REPORT RESUMES

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UNIVERSITY CURRICULA IN THE MARINE SCIENCES.
BY- FROSCH, ROBERT A.
INTERAGENCY COMMITTEE ON OCEANOGRAPHY, WASH., D.C.
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REPORTED IS A COMPILATION OF MARINE SCIENCE COURSES OFFERED AT AMERICAN COLLEGES AND UNIVERSITIES. THE INFORMATION IS PROVIDED TO ASSIST STUDENTS PLANNING A CAREER IN MARINE RESEARCH AND DEVELOPMENT. THREE CURRICULUM AREAS ARE INCLUDED--(1) MARINE SCIENCES, (2) OCEAN ENGINEERING, AND (3) MARINE TECHNOLOGY. LISTED FOR EACH COLLEGE OR UNIVERSITY ARE (1) A BRIEF OUTLINE OF THE PROGRAM AND THE FACILITIES AVAILABLE, (2) THE INSTRUCTIONAL STAFF, (3) THE DEGREES OFFERED, (4) THE UNDERGRADUATE COURSES OFFERED, (5) THE GRADUATE COURSES OFFERED, AND (6) SOURCES OF FURTHER INFORMATION. INFORMATION IS ALSO PROVIDED ON THE TYPICAL REQUIREMENTS FOR UNDERGRADUATE PREPARATION LEADING TO GRADUATE STUDY IN THE MARINE SCIENCES AND ON FINANCIAL ASSISTANCE PROGRAMS AVAILABLE TO STUDENTS IN THE MARINE SCIENCES. THIS DOCUMENT IS ALSO AVAILABLE FROM SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C. 20402. (DS)

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# UNIVERSITY CURRICULA IN THE MARINE SCIENCES

ACADEMIC YEAR
1967-68

Prepared by the Staff of the

INTERAGENCY COMMITTEE ON OCEANOGRAPHY
for the
NATIONAL COUNCIL ON MARINE RESOURCES
AND ENGINEERING DEVELOPMENT

SE 004 093

ICO Pamphlet No. 30
August 1967

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# UNIVERSITY CURRICULA IN THE MARINE SCIENCES

## ACADEMIC YEAR 1967-68

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# FOREWORD

Issued under the broad authority of the National Council on Marine Resources and Engineering Development, "University Curricula in the Marine Sciences" is a compilation of marine science courses offered at American colleges and universities.

By providing information about existing training in the marine sciences,it is hoped that this catalog will aid all students who plan to follow a career in marine research and development. The Marine Sciences Council, the ICO Manpower and Training Panel,who made recommendations regarding the content and format of this report,and the ICO Staff are deeply grateful for the cooperation of the many faculty members of listed institutions who generously supplied the information in this report.

Unlike its predecessor publications, this report lists, separately, curricula in ocean engineering and marine technology. The chart beginning on page 148 shows specific degrees granted in the various marine science specialties. Although some universities prefer scientists to be trained to the baccalaureate level in one of the classical disciplines of science before concentrating their attention entirely upon the marine environment, nearly all of the institutions apply listed course work for credit towards advanced degrees. The omission from this catalog of degrees in biology, geology, and other fields allied to the marine sciences, does not in any way imply that the Interagency Committee on Oceanography considers the system of training which culminates in a degree in "oceanography" preferable to that which channels training through classical scientific disciplines.

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# TYPICAL REQUIREMENTS FOR UNDERGRADUATE PREPARATION LEADING TO GRADUATE STUDY

The following excerpt is quoted from the bulletin of the University of Miami's Institute of Marine Sciences.

"The department receives many inquiries concerning proper undergraduate preparation for entrance to its graduate program. To guide students, several undergraduate programs are suggested for preparation in Fisheries, Marine Biology, Oceanography, and Marine Geology. Other disciplines are not considered since each university has its own set of requirements designed to give students broad exposure to the liberal arts.

Students interested in pursuing marine science should select an undergraduate major in one of the basic scientific disciplines. The undergraduate college should be selected on the basis of curriculum and staff strength in that major. In the biological sciences, Zoology is much preferred to Botany as an undergraduate major but, hopefully zoology students will include basic botany courses in their curriculum. Within the general scope of the program suggested below, prospective marine biology students most interested in experimental biology should take care to be well prepared in chemistry, biochemistry, and mathematics. Students interested in systematics, anatomy, etc., should strengthen their zoology, genetics and related course program.

Prospective marine geologists should acquire strong backgrounds in Mathematics, Chemistry and Physics.

The student should at the same time be careful to satisfy the graduation requirements of his own University. Students should consult their Department for assistance on individual programs.

University College science courses that lack laboratories are not acceptable substitutes for the basic science courses. Students may wish to spend one summer at a marine laboratory in order to have a more firm basis for decision concerning their future career in marine science.

In the suggested curricula on the following pages, courses are designated as "required" (those believed to be essential) and "suggested" (those which should be taken if the student's program can include them).

A student may be admitted to graduate standing in this department without having had some of the required courses, but he will ordinarily not be allowed to take a master's degree until he has completed all of them, either before or after admission to the Graduate School.

Courses listed as "suggested" should be taken whenever the student's program permits, but he will ordinarily not be obliged to take them in order to obtain the master's degree. He may however, be asked to take some of the "suggested" courses if he continues for the Ph.D. degree.

Exceptions to these requirements may be made at the discretion of the department and the student's advisory committee. The reading knowledge of two languages is required of graduate students before the Ph.D. degree can be achieved. Good undergraduate preparation in at least one language is strongly urged. Spanish ordinarily is not an acceptable substitute for French or German or Russian.

Undergraduate courses taken by a graduate student do not contribute credits toward his advanced degree at the University of Miami."

The courses designated as "required" are marked with an asterisk.

## MARINE BIOLOGY

Zoology
- *Introductory or General Zoology
- *Invertebrate Zoology
- *Comparative Vertebrate Anatomy or Vertebrate Zoology
- *Embryology
- *Physiology
- Parasitology
- Histology
- Genetics
- Microscopy and Microtechnique
- Ichthyology

Botany
- *General (8 Hours)
- Phycology

Physics
- *General Physics

Foreign Language
- French, German or Russian

English
- *Composition

Chemistry
- *Principles of Chemistry (Inorganic)
- *Qualitative Analysis
- Organic Chemistry
- Physical Chemistry
- Quantitative Analysis
- Biochemistry

Mathematics
- *Algebra
- *Trigonometry
- *Analytic Geometry
- *Calculus (Differential)
- Statistics, preferably Statistical Methods in Natural Sciences

Geology
- Physical Geology
- Historic Geology

Marine Sciences
- Introduction to Marine Biology
- Introduction to Oceanography

## OCEANOGRAPHY

Physics
- *General Physics
- *Mechanics
- *Thermodynamics
- Modern Physics
- Electricity
- Hydrodynamics
- Theoretical Physics

Chemistry
- *Principles of Chemistry (Inorganic)
- *Qualitative Analysis (2 semesters)
- *Quantitative Analysis
- Physical Chemistry
- Organic Chemistry

Zoology
- *Introduction or General Zoology

Mathematics
- *Algebra
- *Trigonometry
- *Analytical Geometry
- *Calculus
- Differential Equations

Geology
- *Physical Geology
- Sedimentation

Meteorology
- General Meteorology

Marine Sciences
- Introduction to Marine Biology
- Introduction to Oceanography

English
- *Composition

Foreign Language
- German, Russian or French

## FISHERIES

Zoology
- *Introductory or General Zoology
- *Invertebrate Zoology
- *Comparative Vertebrate Anatomy or Vertebrate Zoology
- *Embryology
- *Physiology
- Genetics
- Microscopy and Microtechnique
- Histology
- Parasitology
- Ichthyology
- Limnology

Mathematics
- *Algebra
- *Trigonometry
- *Analytical Geometry
- Statistical (Preferably Statistical Methods in Natural Sciences
- Calculus

Botany
- General Botany
- Bacteriology

Physics
- *General Physics

Chemistry
- *Principles of Chemistry (Inorganic)
- *Qualitative Analysis
- Quantitative Analysis
- Organic Chemistry
- Physical Chemistry
- Biochemistry

English
- *Composition

Foreign Language
- German, Russian or French

Marine Sciences
- Introduction to Marine Biology
- Introduction to Oceanography

## MARINE GEOLOGY

Physics
- *General Physics (2 semesters)
- Thermodynamics
- Modern Physics

Chemistry
- *Chemistry (2 semesters)
- Physical Chemistry
- Qualitative Analysis
- Quantitative Analysis

Mathematics
- *Algebra
- *Trigonometry
- *Analytical Geometry
- *Calculus

Zoology
- *Introductory or General Zoology

Geology
- *General Geology
- *Paleontology
- *Petrology
- *Optical Mineralogy
- *Field Geology
- *Structural Geology
- Stratigraphy
- Sedimentation

Marine Sciences
- Introduction to Marine Biology
- Introduction to Oceanography

English
- *Composition

Foreign Language
- French, German or Russian

# FINANCIAL ASSISTANCE PROGRAMS FOR COLLEGE STUDENTS

## Federally Supported Programs

### National Defense Student Loan Program

Under this program students at all levels - from high school graduates to Ph.D. candidates - may be eligible for long-term, low interest loans.

High school graduates who have been accepted for enrollment by participating colleges and universities as well as graduate and professional students who are enrolled at least half time and who need financial assistance are eligible for student loans.

An eligible undergraduate may borrow up to $1,000 each academic year - to a total of $5,000. An eligible graduate or professional student may borrow as much as $2,500 each year to a maximum of $10,000. Repayment need not begin until 9 months after the student leaves college. Interest on the loan is three percent a year. Up to 50 percent of the loan may be cancelled or "forgiven"at the rate of 10 percent for each year the borrower teaches in a public or other nonprofit elementary or secondary school or in an institution of higher education in the United States and the total loan may be cancelled at 15 percent a year for teaching in certain schools in low-income areas.

### College Work - Study Program

This program supported by the Office of Education and administered by the participating colleges provides students the opportunity to earn part of their college expenses by working within the college or university or for a public or private non-profit organization. While classes are in session, a student may not work more than 15 hours a week. During vacation periods, a student may work 40 hours a week.

### Guaranteed Loan Program for College Students

Students in attendance or accepted for admission in accredited institutions are eligible to borrow for college expenses under the Guaranteed Loan Program (authorized by the Higher Education Act of 1965). In general, depending upon the state in which they live, students may borrow from $1,000 to $1,500 per year. For students whose adjusted family income is less than $15,000 a year, the Federal government will pay all interest charges (six percent) during the time they are in school, and half the interest (three percent) during the repayment period. Repayment does not begin until after studies are terminated.

### Educational Opportunity Grants Program

This program authorized by the Higher Education Act of 1965 provides for grants ranging from $200 to $800 to students of exceptional financial need for each of the four years of undergraduate study. Colleges participating in the program select the student recipients of the grants, and determine the amount the student needs. Any student in extreme financial need who has been accepted for admission at a participating college or who is already enrolled and in good standing is eligible to apply for a grant.

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For further information on these four programs, write to the U.S. Office of Education, Division of Student Financial Assistance, Washington, D. C. 20202.*

* * *

### Junior GI Bill

Under provisions of the Junior GI Bill and its recent amendments, educational allowances are paid to children (generally between the ages of 18-23) of Veterans who were either permanently or totally disabled or who died as a result of service in the U.S. Armed Forces.

### Veterans Readjustment Benefits Act of 1966

This Act provides educational opportunities for qualified servicemen or women who have served in the Armed Forces on active duty for more than 180 days any part of which occurred after January 31, 1955 and for servicemen or women currently on active duty.

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For further information on these two programs, write to any organization for veterans or visit your nearest Veterans Administration Office.*

* * *

### Reserve Officer Training Programs (ROTC)

The Army, Navy, and Air Force maintain reserve officer training programs at selected colleges and universities. Financial assistance grants are available to selected students. After completion of one of these programs, the student is obligated to serve a stipulated period of time in the military service. Inquiries should be directed to the Chairman of the Department of Military Science of the institution in which the student plans to enroll or to the Department of Defense, Washington, D. C. 20301.

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* See bibliography on page 151.

## Other Federal Scholarship or Grant Awards

Many other Federal agencies support small programs of awards limited to students in a particular academic area or to groups with particular ethnic origins. Agencies maintaining such programs for undergraduates include the Department of the Interior through the Bureau of Indian Affairs and the Department of Commerce for students at Maritime Academies. Inquiries about these programs should be addressed to the appropriate Federal agency.

In addition, a majority of the universities have federally supported research programs in the marine sciences. These programs provide funds to graduate students in the form of research fellowships, grants, and teaching stipends. Arrangements for financial support should be made with the appropriate departments at the universities.

## State Programs

A majority of the states and Puerto Rico sponsor financial assistance programs for undergraduate and first professional degree students. The amount and form of assistance as well as eligibility requirements vary among the States. The amount of aid often depends upon such factors as family income and other assets. To be eligible for assistance, students may be required to pass examinations, have superior academic records, or be enrolled in specific fields. Forms of assistance include loans, scholarships and grant-in-aids. Further information on State sponsored programs may be obtained from high school conselors and State departments of education. In addition, sources of financial assistance can be found in Need a Lift.*

## Nongovernmental Scholarships and Loans

Financial assistance programs maintained by local, state, and national units of social, civic, religious, and fraternal organizations provide loans and scholarships to outstanding and worthy students. In addition, many national scholarships are awarded through specific colleges to qualified students by large corporations and foundations.

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* See bibliography on page 151.

## LISTING OF UNIVERSITY CURRICULA BY GEOGRAPHIC LOCATION

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# CHAPTER 1

# CURRICULA IN MARINE SCIENCES

## UNIVERSITY OF ALASKA
College, Alaska 99701

The facilities of the Institute of Marine Science are divided between the University Campus at College (Fairbanks) and the Douglas Marine Station (Juneau).

The College facility contains office space for staff members and graduate students, a departmental conference room, and specialized research areas. These include laboratories for research in biochemistry, radio and stable isotopes, chemistry, microbiology, and physical oceanography. There are three controlled temperature rooms, two darkrooms, and a drafting room. Other facilities available on campus are the University library and IBM 1620 and 360 computers.

The marine facilities near Juneau include administrative offices, laboratories, library, darkroom workshops, storage space, and docking facilities for the Institute's vessels. Nearby is Mt. Jumbo school which is being converted to provide accommodations for staff members and about 20 students. When completed in the spring of 1967, it will also have a fully equipped mechanical workshop, warehouse, storage lockers, work and lecture rooms.

The Institute's vessels are the well-equipped 80 ft. AGONA, the 43 ft. MAYBESO, and small craft and work rafts. The AGONA is equipped with a bow propellor for easy maneuvering, two winches and a boom for handling heavy equipment over the side, and a hydrographic winch for standard sampling and light work.

Instructional Staff:

DONALD W. HOOD, Ph.D., Professor and Director, Chemical Oceanography
MARY BELLE ALLEN, Ph.D., Professor Marine Algology and Microbiology
JOHN J. GOERING, Ph.D., Associate Professor, Biological Oceanography
ROBERT J. BARSDATE, Ph.D., Assistant Professor, Chemical Oceanography
DAVID C. BURRELL, Ph.D., Assistant Professor, Geochemistry
SHERIL D. BURTON, Ph.D., Assistant Professor, Microbiology
DON K. BUTTON, Ph.D., Assistant Professor, Biochemistry
VERA A. DUGDALE, Ph.D., Assistant Professor, Limnology
CHARLES M. HOSKIN, Ph.D., Assistant Professor, Sedimentology
PATRICK J. KINNEY, Ph.D., Assistant Professor, Chemical Engineering
LEONARD I. KNOWLES, M.S., Assistant Professor, Geochemistry
J. BRIAN MATTHEWS, Ph.D., Assistant Professor, Physical Oceanography
KOTTAYAM V. NATARAJAN, Ph.D., Assistant Professor, Marine Microbiology
DONALD H. ROSENBERG, M.S., Assistant Professor, Physical Oceanography
GHANSHYAM D. SHARMA, Ph.D., Assistant Professor, Marine Geology
FREDERICK F. WRIGHT, Ph.D., Assistant Professor, Marine Geology

Degrees Offered:

Master of Science in Geology, Chemistry, or Physics with Marine Science option.
Doctor of Philosophy in Marine Science

Students may pecialize in biological, microbiological, b ochemical, chemical, geological and phy ical oceanography.

Courses Offered:

Undergraduate Cour es

Geology 411 GENER L OCEANOGRAPHY
Wright

Description o the oceans and ocean processes; in er-relation of disciplinary sciences to the field; history of oceanography, modern developments and trends in the field. Prerequisites: Senior or graduate status in a disciplinary science, mathematics, or engineering.

Graduate Courses

Physics 645 PHYSIC L OCEANOGRAPHY
Matthews

Physics of the sea and physical properties; light an sound transmission: hydrostatics, turbulence; currents; upwelling; hea and water budgets; water mass identific tion and transport; sea ice. Prerequi ites: One year of general physics and ma hematics through calculus; one semester o geology or permission of the instructor

Biology 652 MARINE ECOLOGY

The sea as a b ological environment; organisms in t e ocean; factors influencing the growth of organisms; nutrient cycles; produc ivity; food web and interdependence of organisms. Prerequisites: quantitative analysis and one year of organic chemistry; 8 credits of general bio ogy; and permission of the instructor.

Biology 641 MICROBI AL PHYSIOLOGY

Organism isolation; growth of cultures; fermentation; enzyme purification; amino acid metabolism and synthesis. Prerequisites: One year of microbiology; one year of biochemistry; or permission of instructor.

**Chemistry 641 CHEMICAL OCEANOGRAPHY**

Chemical composition and properties of sea water; evaluation of salinity, pH, excess base, and carbon dioxide system; interface reactions; dissolved gases; organic components and trace inorganic components. Prerequisites: Quantitative analysis; one year of organic and physical chemistry; or permission of the instructor.

**Chemistry 642 ADVANCED CHEMICAL OCEANOGRAPHY**
Hood

Selected topics in chemical oceanography, including stable isotope chemistry; chemical equilibria; chemistry of marine biota and their products; interaction of sediments and water; material exchange through sea air interface; marine photosynthesis and several topics of marine biochemistry; chemistry technology as applied to oceanography; raw materials and industrial utilization. Prerequisites: Chemical Oceanography 1, or permission of the instructor.

**Chemistry 645 CELLULAR BIOCHEMISTRY**
Button

Hetertrophic metabolism, autotrophic processes; control mechanisms, including enzymes and mechanism of reaction control; cellular nutrition, including growth kinetics. Prerequisites: One year of biochemistry or equivalent, or permission of the instructor.

**Geology 613 MARINE GEOLOGY**
Hoskin

Survey of marine geology structure of ocean basins and continental margins; chemical and physical properties of marine sediments; geological processes in the oceans. Prerequisites: One course in geochemistry; one year physical chemistry; one year general chemistry; and mathematics through calculus; or permission of the instructor.

**Mar 697, 698, 797, 798**
Staff

Review of current research in oceanoraphy.

Person to be contacted for further information:

Dr. Donald W. Hood, Director
Institute of Marine Science
University of Alaska
College, Alaska 99701

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## UNIVERSITY OF THE PACIFIC
Stockton, California 95204

PACIFIC MARINE STATION
Dillon Beach, California 94929

The Pacific Marine Station provides opportunities for study and research in marine biology and related fields of science. The facilities include laboratories, a library, a research museum, darkrooms, and living accommodations. A 38 foot converted landing craft, BIOS PACIFICA, a 16 foot Boston Whaler and a 26 foot whaleboat are available.

Undergraduate and graduate courses are offered during the summer sessions on a non-matriculation basis. These courses are accepted by many university departments in fulfillment of advanced degree requirements for study at a marine station. Usually two formal courses are offered during the seven week summer session, one of which is given by a visiting instructor from another institution. During the academic year there are opportunities for advanced study in problems of marine ecology and invertebrate zoology.

Students from other colleges who desire to study at Pacific Marine Station should plan to begin their program by attending classes at the Station during the summer session before taking up academic year residence at Dillon Beach; formal admission procedures may be deferred until the fall semester.

Instructional Staff:

EDMUND H. SMITH, Ph.D., Director, Pacific Marine Station; Assistant Professor of Zoology, University of the Pacific
JOHN S. TUCKER, Ph.D., Research Associate Professor, Pacific Marine Station; Associate Professor of Natural Science, Raymond College
WALTER HEWITSON, Ph.D., Visiting Assistant Professor of Biological Sciences, University of the Pacific
RALPH G. JOHNSON, Ph.D., Adjunct Professor of Paleontology, University of the Pacific (Pacific Marine Station); Associate Professor of Paleontology, University of Chicago
VICTOR L. LOOSANOFF, Ph.D., Adjunct Professor of Marine Biology, University of the Pacific (Pacific Marine Station)
ARTHUR T. BRICE, M.A., Adjunct Professor of Microbiology, Phase Contrast, University of the Pacific (Pacific Marine Station)
RAYMOND A. UNDERHILL, Ph.D., Research Associate, (polychaete development and ecology)

Degrees Offered:

Master of Science

Courses Offered:

Graduate

Regular Session Courses
(Pacific Marine Station)

112. INVERTEBRATE ZOOLOGY
Smith

The functional morphology, taxonomy, embryology, ecology, phylogeny, and economic importance of the invertebrates. Lectures, laboratory, field trips, and individual reports. Prerequisite: One year of college zoology or marine biology.

249. COMPARATIVE HISTOLOGY AND MICROTECHNIQUE
Smith

Comparative histological investigation of vertebrate and invertebrate tissue with training in the preparation for microscopic examination of animal structures, tissues, cells and whole mounts. Prerequisite: General Zoology.

Graduate and Undergraduate

Summer Session Courses
(Pacific Marine Station)

S112. INVERTEBRATE ZOOLOGY
Staff

The functional morphology, taxonomy, ecology, and phylogeny of the invertebrates. Lectures, laboratory, field trips, and individual reports. Prerequisite: One year of college zoology.

S124. MARINE BOTANY (ALGOLOGY)
Staff

Emphasis on morphology and taxonomy of local marine algae with consideration of some ecological, physiological, and economic aspects. Lectures, laboratory, field trips, and individual problems. Prerequisite: A course in general botany.

S137. MARINE PALEONTOLOGY
Staff

The biological aspects of marine paleontology will be stressed. Lectures, laboratory and field trips. Recommended: A course in introductory geology and biology.

Person to be contacted for further information:

Edmund H. Smith, Director
Pacific Marine Station
Dillon Beach, Marin County
California 94929

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## HOPKINS MARINE STATION OF STANFORD UNIVERSITY
Pacific Grove, California 93950

DEPARTMENT OF BIOLOGICAL SCIENCES

Founded in 1892, the Station was the first marine laboratory to be established on the American Pacific Coast. It operates as a branch of the Department of Biological Sciences of the University, and is primarily a graduate school. It provides year around facilities for visiting investigators and for graduate students working toward the M.A. or Ph.D. in biology. Advanced classes in various aspects of marine biology and biological oceanography are offered, and these are open to qualified students from any college or university and to teachers of biology.

The teaching and research facilities at the Station are housed in three main buildings provided with running seawater, the Alexander Agassiz Laboratory, the Jacques Loeb Laboratory, and the Marinostat. Cold rooms, constant temperature rooms, and a photographic darkroom are available. The laboratories are equipped with a wide variety of specialized equipment. The library is housed on the upper floor of the Jacques Loeb Laboratory. It contains a constantly expanding collection of books in the fields most under study (algology, invertebrate zoology, development, ecology, physiology, biochemistry, microbiology, and biological oceanography).

The research vessel TE VEGA, a 135-foot two-masted, steel-hulled schooner capable of sustained operations at sea provides the base for graduate training in biological oceanography. The ship carries a scientific party of 15 and is outfitted as a floating laboratory for observation, collection, experimentation, and teaching. Deep sea trawling and hydrographic winches permit sampling at depths of up to 6000 meters. In addition to a variety of gear for physical measurement, chemical analysis, and the collection, examination and maintenance of living organisms, the ship carries a small reference library which is changed to suit the needs of each cruise. Several skiffs and a launch for inshore work are carried on deck. Each year the vessel conducts four cruises, each cruise lasting for one academic quarter.

A second research vessel the TAGE, a 40.5 foot launch equipped with winch and 1000 meters of 1/4 inch cable, is used for two netting, trawling, dredging, and hydrographic sampling in Monterey Bay.

Instructional Staff:

DONALD PUTNAM ABBOTT, Ph.D., Professor of Biology and Associate Director, Hopkins Marine Station
ISABELLA AIONA ABBOTT, Ph.D., Research Biologist
LAWRENCE ROGERS BLINKS, Ph.D., Acting Professor of Biology, Emeritus
DAVID EPEL, Ph.D., Assistant Professor of Biology

**ARTHUR CHARLES GIESE**, Ph.D., Professor of Biology
**MALVERN GILMARTIN**, Ph.D., Professor of Biological Oceanography
**WELTON LINCOLN LEE**, Ph.D., Assistant Professor of Biology
**RICHARD EARL NORRIS**, Ph.D., Acting Associate Professor of Botany
**JOHN HOWELL PHILLIPS**, Ph.D., Associate Professor of Biology and Director, Hopkins Marine Station
**GEORGE JACOB HOLLENBERG**, Ph.D., Acting Professor of Biology, Stanford

Degrees Offered:

Doctor of Philosophy in Biology

Students may specialize in any of the following fields: algology, invertebrate zoology, development, ecology, physiology, biochemistry, and biological oceanography.

Undergraduate Courses

100h MARINE ALGAE
Hollenberg, I. Abbott

Lectures, laboratory, and field work on the various classes of algae. Particular attention will be given to the marine algae of the Pacific Coast.

111h MARINE INVERTEBRATES
D. Abbott

Survey of the lower marine invertebrates, echinoderms, and protochordates. Emphasis is placed on basic body plan, functional anatomy, pattern of development, higher classification, and phylogenetic relationships rather than of detailed morphology and species identification.

112h MARINE INVERTEBRATES (Continued)
D. Abbott

Continuation of Course 111h, covering the molluscs, annelids, arthropods, and allied lesser phyla. While the two courses form a continuous sequence, either half may be taken separately.

118h PHYTOPLANKTON
Norris, I. Abbott

Lectures, laboratory and field work on inshore and some open sea phytoplankton with special emphasis on morphology and systematics. Groups to be covered are Euglenophyta, Chlorophyta, Pyrrophyta, Chrysophyta and Cyanophyta.

119h MARINE ECOLOGY
Lee

Ecological studies on the ecology of selected marine associations and habitats. Emphasis is placed on the morphological and physiological adaptations of marine animals to their environment.

120h MARINE ECOLOGY
Lee

Continuation of 119h with special emphasis on group projects.

147h COMPARATIVE EMBRYOLOGY
Epel

A lecture and laboratory course surveying developmental patterns, and their experimental modifications in marine invertebrates, fishes, and algae.

148h COMPARATIVE EMBRYOLOGY
Epel

Continuation of 147h.

175h PROBLEMS IN MARINE BIOLOGY
Department Staff

Lectures, laboratory work, field studies and individual problems. The course is designed primarily to give undergraduates an opportunity to engage in research. Students will spend the entire spring quarter in residence at Pacific Grove.

199h SPECIAL PROBLEMS
Department Staff

Properly qualified undergraduates may undertake individual work in the fields indicated under Course 300h.

Graduate Courses

222h BIOLOGICAL OCEANOGRAPHY
Gilmartin

An intensive introduction to the organisms and environment of the open sea and to the concepts, problems, and methods of biological oceanography. Studies are carried out aboard R/V TE VEGA in oceanic regions which vary from quarter to quarter. Students participate with the faculty in the study of selected problems.

261h COMPARATIVE BIOCHEMISTRY OF MARINE ORGANISMS
Phillips

The chemistry of sea water, and the role of organisms with respect to it. Important cycles of matter in the ocean, and the differing biochemical pathways involved in representative microorganisms and animals.

264h PHYSIOLOGY OF ALGAE
Blinks

Lectures and experiments on the physiology of fresh-water, epiphytic, marine and brine algae. Osmotic and salt effects, permeability, respiration, pigments, photosynthesis and tropisms are among the topics studied.

269h ECOLOGICAL PHYSIOLOGY
Giese

Physiological responses of animals to variations in environmental factors and to organisms. Most of the work will deal with marine invertebrates.

300h RESEARCH
Department Staff

Graduate study involving orginal work may be undertaken with members of the staff in the fields indicated: Marine Zoology, Developmental Biology, Physiology, Biological Oceanography, Ecology, and Biochemistry and Immunology.

Person to be contacted for further information:

Dr. John H. Phillips, Jr., Director
Hopkins Marine Station of Stanford University
Pacific Grove, California 93950

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## HUMBOLDT STATE COLLEGE
Arcata, California 95521

The marine science programs at Humboldt State College offer instruction and opportunities for research in marine fisheries, oceanography, and the marine aspects of zoology, botany, and ecology. Present facilities include saltwater aquaria, a water chemistry laboratory, ichthyology laboratories, and zoology and botany classrooms and laboratories. A 40-foot research vessel equipped with standard oceanographic and biological instrumentation is available. A marine sciences laboratory with a modern saltwater system is located at Trinidad, California.

Instructional Staff:

Division of Natural Resources

GEORGE H. ALLEN, Ph.D., Professor of Fisheries
GEORGE F. CRANDELL, Ph.D., Assistant Professor of Oceanography
JOHN W. DeWITT, Ph.D., Professor of Fisheries
JAMES A. GAST, Ph.D., Associate Professor and Coordinator of Oceanography, Director of Marine Laboratory
RICHARD L. RIDENHOUR, Ph.D., Associate Professor and Coordinator of Fisheries
ROBERT W. THOMPSON, Ph.D., Assistant Professor of Oceanography

Division of Biological Sciences

WILLIAM V. ALLEN, Ph.D., Assistant Professor of Zoology
GARY BRUSCA, Ph.D., Assistant Professor of Zoology
JOHN D. DeMARTINI, Ph.D., Associate Professor of Zoology
WARREN J. HOUCK, Ph.D., Professor of Zoology
ROBERT A. RASMUSSEN, Ph.D., Assistant Professor of Botany
JAMES F. WATERS, Ph.D., Assistant Professor of Biology

Degrees Offered:

Division of Natural Resources

Bachelor of Science in Fisheries
Master of Science in Fisheries
Bachelor of Science in Oceanography

Division of Biological Sciences

Bachelor of Arts in Biology
Master of Arts in Biology
Bachelor of Arts in Botany
Bachelor of Arts in Zoology

Courses Offered:

Division of Natural Resources

Department of Fisheries

Undergraduate Courses

Upper Division

100 INTRODUCTION TO FISHERY BIOLOGY
Staff

Identification, life histories, and ecology of important freshwater and marine fishes. Basic principles of fisheries management and relationships with the management of other resources. Designed for students of game management, forestry, and other natural resource areas except fisheries.

102 FIELD COURSE IN FISHERY BIOLOGY
Staff

Selected topics on freshwater or marine fishes and their biology. When possible, classes will be held at the marine station or in the field. Designed for high school biology teachers, students majoring in general biology, and other non-fisheries majors.

110A ICHTHYOLOGY
Allen

Introduction to ichthyology and identification, life history, and ecology of important commercial, game and forage species.

110B ICHTHYOLOGY
Allen

Comparative anatomy and elementary physiology of cyclostomes chondrichthyes, and osteichthyes.

### 110C ICHTHYOLOGY
Allen

Speciation, evolution and classification of fishes.

### 126 PROBLEMS IN WATER POLLUTION BIOLOGY
DeWitt

The nature, scope, magnitude, and significance of water pollution; common pollutant materials, their nature and sources, and their effects in natural waters. Detection, surveillance, and abatement of water pollution.

### 135 ECOLOGY OF MARINE FISHES
Allen

Environmental influences on the life history, behavior, growth, and survival of marine and anadromous fishes.

### 150 INTRODUCTORY FISH POPULATION DYNAMICS
Allen, Ridenhour

Concepts of population growth, standing crop, carrying capacity, yield, production, recruitment, and survival.

### 160 PRINCIPLES OF FISHERY MANAGEMENT
Staff

Principles and practices of administration and management of fish populations.

### 170 FISH CULTURE AND BREEDING
DeWitt, Ridenhour

The culture and breeding of freshwater and marine sports, commercial, and aquarium fin-fishes and shellfishes. The operation of fresh and saltwater hatcheries and aquaria. The care and use of fishes as experimental animals.

### 175 COMMERCIAL FISHERIES
Allen

Location of and species taken in commercial fisheries and their importance to the world food supply. Methods of harvest and products marketed. Economic problems of common property resources.

### 180 TECHNIQUES IN FISHERY BIOLOGY
Staff

Research methods including analysis of age and growth, fecundity, and food habits, population enumeration, analysis of yield, and fishery statistical systems.

### 184 FISHERIES INSTRUMENTATION, GEAR, AND METHODS
Allen

Field and laboratory instruments, gear, and methods used in research, management, and development of fisheries and in the commercial and sport fishing industries.

### 195 FIELD PROBLEMS IN FISHERIES
Staff

Individual work on specific problems in fisheries.

### 198 SENIOR FISHERIES SEMINAR
Staff

Discussion and review of selected topics in fisheries.

## Graduate Courses

### 240 EARLY LIFE HISTORY OF FISHES
Allen

Reproduction, embryology, and identification of eggs and larvae of fishes. Methods of sampling eggs and larvae and associated analytical methods.

### 245 ECONOMICALLY IMPORTANT INVERTEBRATES
Staff

Life history, ecology, and identification of invertebrates of sport and commercial importance.

### 250 ADVANCED FISH POPULATION DYNAMICS
Allen, Ridenhour

Examination and development of population models emphasizing the effects of exploitation.

### 260 ADVANCED PRINCIPLES OF FISHERIES MANAGEMENT
Staff

New and advanced theories, principles, and techniques in fisheries management.

### 290 THESIS
Staff

Preparation of the written thesis required for the graduate degree.

### 295 RESEARCH PROBLEMS IN FISHERIES
Staff

Individual research on advanced field or laboratory problems.

### 298 GRADUATE FISHERIES SEMINAR
Staff

Discussion and review of selected advanced topics in fisheries.

## Department of Oceanography

## Undergraduate Courses

### Upper Division

### 100 GENERAL OCEANOGRAPHY
Staff

Introduction to oceanography including the study of the extent of the oceans; the chemical nature of sea water; causes and effects of currents and tides; animal and plant life in the sea.

101 BIOLOGICAL OCEANOGRAPHY
Crandell

Physical, chemical, and biological factors characterizing the marine environment; factors controlling plant and animal populations; methods of sampling, identification and analysis.

102 PHYSICAL OCEANOGRAPHY
Gast

Physical properties and processes in the seas; theory of the distribution of variables; theory and practice of current determination; waves and tides.

103A, 103B CHEMICAL OCEANOGRAPHY
Gast

Physical and chemical properties of sea water and sea products; methods of quantitative analysis.

105 METHODS AND INSTRUMENTS OF OCEANOGRAPHY
Staff

Practical experience with the types of measuring and sampling devices used at sea and ashore; methods of observing, recording, and presenting oceanographic data; means of locating positions.

106 GEOLOGICAL OCEANOGRAPHY
Thompson

Classification and origin of the major topographic features on the ocean floor; survey of recent marine sediments and sedimentary processes; effects of Pleistocene sea-level fluctuations.

112 ADVANCED PHYSICAL OCEANOGRAPHY
Gast

Introduction to marine hydrodynamics; equations of continuity and motion; methods for solving problems in physical oceanography.

116 MARINE SEDIMENTATION
Thompson

Source, transportation, and depositional environments of recent marine sediments; practical study of composition and textural properties; application of recent sediments studies to the interpretation of ancient rocks.

121 ZOOPLANKTON ECOLOGY
Crandell

Identification, distribution, abundance, adaptations and life histories for animals in the plankton with a consideration of methods and techniques used in field and laboratory studies.

125 FIELD PROBLEMS
Staff

Research on assigned topics which may involve laboratory work or field work.

126 BEACH AND NEARSHORE PROCESSES
Thompson

Topography and sediments of shorelines and coasts; study of the physical processes in the nearshore environment, including waves and littoral currents.

131 MARINE RADIOECOLOGY
Staff

Principles of tracer techniques, procedures for radio-assay, limitations of tracer methodology, hazards, safe handling proceedures, and factors influencing disposal of radionuclides in the marine environment.

180 UNDERGRADUATE SEMINAR
Staff

Review of the history and literature of oceanography, applications of marine sciences.

181 SEMINAR IN BIOLOGICAL OCEANOGRAPHY
Crandell

Review of the literature and discussion of selected topics.

182 SEMINAR IN PHYSICAL OCEANOGRAPHY
Gast

Review of the literature and discussion of selected topics.

183 SEMINAR IN CHEMICAL OCEANOGRAPHY
Gast

Review of the literature and discussion of selected topics.

186 SEMINAR IN GEOLOGICAL OCEANOGRAPHY
Thompson

Review of the literature and discussion of selected topics.

190 FIELD CRUISE
Staff

Participation in an extended cruise covering shipboard utilization of oceanographic theory and practices.

199 INDEPENDENT STUDY
Staff

Original research on assigned topics which may involve laboratory work, field work or literature surveys.

## Division of Biological Sciences

### Department of Biology

### Undergraduate Courses

#### Upper Division

141 MARINE BIOLOGY
Brusca, Rasmussen

The natural history, classification, and adaptations of marine organisms with major emphasis on local forms. Designed primarily for the non-biology major. Participation on field trips as schedules is required.

## Department of Botany

### Undergraduate Courses

#### Upper Division

145 MARINE PHYCOLOGY
Rasmussen

The morphology and taxonomy of marine alage with emphasis on the sessile forms: Rhodophyta, Phaeophyta, and Chlorophyta.

### Graduate Courses

231 MARINE MYCOLOGY
Staff

Taxonomy and morphology of aquatic fungi with emphasis on marine fungi, collection, and culture methods. Offered only during the summer at the Trinidad Marine Laboratory.

245 PHYSIOLOGICAL ECOLOGY OF SEAWEEDS
Rasmussen

Relationships of physical and biological factors to the distributions of littoral and benthic marine algae. Field and laboratory experimentation. Offered only during the summer at the Trinidad Marine Laboratory.

## Department of Zoology

### Undergraduate Courses

#### Upper Division

112 INVERTEBRATE ZOOLOGY
DeMartini, Brusca, Staff

A study of the comparative and functional morphology, adaptations, life histories and phylogeny of the following taxa: Porifera, Cnidaria, Turbellaria, Nematoda, Annelida, Mollusca, Crustacea and Echinodermata.

142 ECOLOGY OF MARINE ANIMALS
Brusca, Staff

An intensive study of the interactions of the environment on the distribution, growth, reproduction, and general biology of marine organisms.

143 INVERTEBRATE PHYSIOLOGY
Allen

A comparative survey of physiological processes in marine, freshwater, and terrestrial invertebrates.

### Graduate Courses

212 ADVANCED INVERTEBRATE ZOOLOGY
DeMartini, Brusca

A study of the comparative and functional morphology, adaptations, life histories and phylogeny of the following taxa: Ctenophora, Rhynchocoela, Aschelminthes, Sipunculida, Echiurida, Ectoprocta, Entoprocta, Brachiopoda, Phoronida, Chaetognatha, Hemichordata, and Urochordata.

242 BENTHIC ECOLOGY
Staff

A study of the sublittoral marine environment, with an emphasis on original literature concerning synecological investigations.

244 INVERTEBRATE EMBRYOLOGY
Waters, Brusca

Study of the early development of selected marine invertebrates, chiefly from living embryos. Although main emphasis is on normal embryology, certain experimental work is included. Offered only during the summer at Trinidad Marine Laboratory.

Person to be contacted for further information:

Dr. James A. Gast
Director, Marine Laboratory
Humboldt State College
Arcata, California 95521

* * *

## NAVAL POSTGRADUATE SCHOOL

Monterey, California 93940

### DEPARTMENT OF METEOROLOGY AND OCEANOGRAPHY

The Department offers advanced education in oceanography for naval officers. The oceanography curriculum is designed to provide officers with an education in physical oceanography with particular emphasis on naval operations, and to enable them through advanced study to conduct independent research. The curriculum affords the opportunity to qualify for the degree Master of Science in Oceanography, with a particular capability in physical oceanography. At the present time the Department operates a 63 foot hydrographic research vessel and has modest laboratory facilities ashore. An extensive Ocean Science Laboratory is to be built on beach front property in 1969. A larger research vessel and dock facilities will also be acquired within the next 5 years.

Instructional Staff:

- GEORGE J. HALTINER, Ph.D., Department Chairman and Professor, Meteorology
- GLENN H. JUNG, Ph.D., Professor, Oceanography
- WARREN C. THOMPSON, Ph.D., Professor, Oceanography
- EUGENE C. HADERLIE, Ph.D., Associate Professor, Oceanography
- JOSEPH J. VON SCHWIND, M.S., Associate Professor, Oceanography
- JACOB B. WICKHAM, M.S., Associate Professor, Oceanography
- WARREN W. DENNER, M.S., Assistant Professor, Oceanography
- THEODORE GREEN III, Ph.D., Assistant Professor, Oceanography
- CHARLES F. ROWELL, Ph.D., Assistant Professor, Chemistry

Degrees Offered:

At Present

Master of Science in Oceanography

Planned

Master of Science in Biological Oceanography (1968)
Master of Science in Geological Oceanography (1968)
Master of Science in Oceanographical Engineering (1969)
Master of Science in Marine Geophysics (1969)
Doctor of Philosophy in Oceanography (Physical) (1970)

Courses Offered:

Undergraduate Courses

Lower Division

None

Upper Division

Oc 2110 INTRODUCTION TO OCEANOGRAPHY
Staff

An introductory course treating physical and chemical properties of sea water, submarine geology, and marine biology; the heat budget of the oceans; water masses and general circulation; currents, waves, and tides.

Graduate Courses

Oc 3260 SOUND IN THE OCEAN
Jung, Denner

Designed for students in the meteorology curricula. A brief introduction to physics of underwater acoustics followed by detailed discussion of oceanographic factors affecting sound transmission in the ocean including absorption, reflecting from the surface and from the bottom, refraction, scattering, and ambient noise.

Oc 3320 GEOLOGICAL OCEANOGRAPHY
Thompson

Physiography of the sea floor, especially continental shelves and slopes, submarine canyons, coral reefs, and the deep-sea floor; properties and distribution of sediments and rates of deposition; structure and origin of the ocean basins.

Oc 3420 BIOLOGICAL OCEANOGRAPHY
Haderlie

General biological principles; the sea as an environment for life; major plant and animal groups in the sea; plankton and food cycles; primary productivity; boring and fouling organisms; bioacoustics, bioluminescence, and deep scattering layers; dangerous marine organisms; physiology and shallow water diving. Laboratory work and field trips dealing with marine organisms.

Oc 3520 CHEMICAL OCEANOGRAPHY
Rowell

Basic chemistry of solutions; chemical composition of the oceans (dissolved solids, gases, nutrients, etc.); distribution of constituents in the ocean; analytical methods used in chemical oceanography; carbonate, nutrient. and other cycles in the sea; desalinisation; corrosion; geochemistry.

Oc 3611 OCEAN WAVE AND SURF FORECASTING
Staff

Course designed for students in the meteorology curricula. Statistical and spectral properties of waves; wave observations and analysis of wave records; the generation, propagation, and attenuation of sea and swell; techniques used in the forecasting of sea and swell; transformation of waves in shallow water.

Oc 3615 OCEAN WAVE AND SURF FORECASTING LABORATORY
Staff

Laboratory course taught in conjunction with Oc 3611. Exercises in forecasting sea and swell generated under various synoptic weather conditions and in surf forecasting.

Oc 3700 OCEANOGRAPHIC INSTRUMENTATION AND OBSERVATIONS
Staff

Theory of design and operation of oceanographic instruments; recording of oceanographic observations, measurements, and samples on log sheets.

Oc 3710 FIELD EXPERIENCE IN OCEANOGRAPHY
Staff

Laboratory course taught in conjunction with Oc 3700. Use of standard oceanographic instruments in the conduct of a comprehensive oceanographic survey; processing and storage of data and samples; interpretation of results.

Oc 3220 DESCRIPTIVE OCEANOGRAPHY
Staff

Properties of sea water; water masses, currents, and three-dimensional circulation in all oceans; distribution of temperature, salinity, and oxygen; temperature-salinity relationships.

Oc 3601 OCEAN WAVE FORECASTING
Staff

Statistical and spectral properties of ocean waves; the generation, propagation, and attenuation of surface wind waves in deep water; spectral and other forecasting techniques; wave observations and analysis of data.

### Oc 3605 OCEAN WAVE FORECASTING LABORATORY
Staff

Laboratory course taught in conjunction with Oc 3601. Exercises in wave observation, the analysis of wave records, forecasting of seas generated under various synoptic weather conditions, and forecasting of swell.

### Oc 3616 OCEANOGRAPHIC FORECASTING
Jung

Space and time variation of ocean density structure and associated parameters; behavior of vertical and horizontal temperature gradients; development of synoptic forecasting techniques applied to the upper ocean; air-sea interaction; advection and mixing effects on ocean density structure. Interpretation in terms of sound propagation paths and sonar range.

### Oc 3621 OCEANOGRAPHIC FORECASTING LABORATORY
Jung

Laboratory exercises illustrate principles developed in Oc 3616 using actual air and ocean data, available forecasting techniques (ASWEPS, and others), and range manuals. Forecasting of sea surface temperature, mixed-layer depth, and sonar range.

### Oc 4211 WAVES AND TIDES
Staff

Theory of surface waves of small amplitude; theory of finite amplitude waves, wind-wave spectra; theory of the astronomical tides; tide analysis and prediction; tidal oscillations in ocean basins; tidal currents.

### Oc 4213 COASTAL OCEANOGRAPHY
Thompson

Transformation of waves in shoal water; surf forecasting; storm tides; nearshore water circulation and littoral drift; characteristics of beaches and coasts.

### Oc 4251 DYNAMICAL OCEANOGRAPHY I.
Green, Wickham

The equations of relative motion, incompressible flow, energy conservation, vorticity, turbulence and diffusion, and boundary layer flow in the ocean. Special cases of flow in the sea, particularly geostrophic motion.

### Oc 4252 DYNAMICAL OCEANOGRAPHY II.
Green, Wickham

The wind-driven circulation and topographical influence on ocean currents; non-linear theories of the wind-driven circulation; the equation of state; convection cells; general treatment of thermal motions; theories of the thermocline and the deep thermohaline circulation.

### Oc 4253 DYNAMICAL OCEANOGRAPHY III.
Green, Wickham

Laws of thermodynamics with applications to ideal gases, to the real atmosphere, and to sea water; thermohaline circulation; stability analysis.

### Oc 4260 SOUND IN THE OCEAN
Jung, Denner

An introduction to the physics of underwater acoustics followed by a detailed discussion of the oceanographic factors affecting sound transmission in the ocean, including absorption, reflection from the surface and bottom, refraction, scattering, and ambient noise in the ocean; normal mode propagation; recent Navy developments.

### Oc 4340 MARINE GEOPHYSICS
Thompson, Denner

Gravity, magnetism, seismicity, and other geophysical characteristics of the oceans and sea floor. Physical properties and composition of the sea floor. Structure of the earth's crust and upper mantle. Origin of the ocean basins and formation of major sea-floor features.

### Oc 4421 MARINE ECOLOGY
Haderlie

The habits, classification, development, and adaptations of marine animals and plants with particular reference to the ecology of Monterey Bay. The relationships of physical, chemical, geological, and biological factors of the environment of marine organisms. Primarily laboratory investigations and field work dealing with the intertidal area, harbors, estuaries, and the nearshore pelagic and benthic environments of the associated organisms.

### Oc 4612 POLAR OCEANOGRAPHY
Wickham, Denner

Marine geography of the Arctic; sea-ice observations, properties, formation, growth, deformation, and disintegration; sea-ice drift due to wind and currents.

### Oc 4900 SEMINAR IN OCEANOGRAPHY
Staff

Students in the environmental sciences curricula conduct original research or summarize the literature in oceanography concerning a special topic, and during their last term present their findings in group discussion. Independently of this, the recent literature in various fields is surveyed, and important papers are presented by individual students.

Person to be contacted for further information:

Professor George J. Haltiner, Chairman
Department of Meteorology and Oceanography
Naval Postgraduate School
Monterey, California 93940

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## POMONA COLLEGE
Claremont, California 91713

During a portion of each summer, Pomona College contracts with the California Institute of Technology for use of the Kerckhoff Marine Laboratory facilities at Corona del Mar. The Laboratory has facilities for teaching and research in marine zoology, embryology, and physiology. Pomona College's five-week summer program, offered at the Laboratory to undergraduates, is intended to serve only as an introduction to marine biology.

Instructional Staff:

MICHAEL G. HADFIELD, Ph.D., Assistant Professor of Zoology

Degrees Offered:

None

Courses Offered:

Department of Zoology

S130 MARINE INVERTEBRATES

A study of invertebrates residing in the sea: their phylogenetic relationship, their morphology, and their physiology. Laboratory devoted principally to Pacific Coast types.

S150 MARINE ECOLOGY

A study of marine invertebrates as they exist in the field. Discussion of the distribution of each species observed and the factors which may account for these distributional patterns.

Person to be contacted for further information:

Dr. Michael G. Hadfield
Department of Zoology
Seaver Laboratory
Pomona College
Claremont, California 91713

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## SAN DIEGO STATE COLLEGE
San Diego, California 92115

The marine sciences program at San Diego State College provides for instruction and research in biological and physical oceanography and the marine aspects of biology, chemistry, engineering, and geology. There is no separate department offering work toward a degree in oceanography; however, a student may specialize in the marine sciences in the departments of biology, botany, chemistry, engineering, geology, physics and zoology. Programs in chemical, geological, and physical oceanography and oceanographic engineering are currently being developed. Staff and student research is being conducted in many areas of marine science with particular emphasis on nearshore problems and the effects of man's activities on marine organisms and the marine environment.

In addition to modern, well-equipped laboratory and shop facilities in all departments, provisions for marine instruction and research include standard equipment for the sampling and laboratory analysis of sea water, extensive benthic and pelagic biological sampling equipment, radioisotope, x-ray, and electron microscope laboratories, constant temperature rooms, and closed-system sea water aquaria. Library holdings are well represented in the marine sciences. Computer facilities are available on the campus. Two small craft, one equipped with a fathometer and hydrographic winch, are available for coastal sampling operations. The use of ocean-going research vessels and marine laboratory space can be arranged.

Instructional Staff:

EDWIN C. ALLISON, Ph.D., Associate Professor of Geology
RICHARD W. BERRY, Ph.D., Associate Professor of Geology
RONALD W. CRAWFORD, Ph.D., Professor of Zoology
RICHARD L. DARBY, Ph.D., Assistant Professor of Biology
DEBORAH M. DEXTER, Ph.D., Assistant Professor of Zoology
DAVID A. FARRIS, Ph.D., Professor of Biology
RICHARD K. FERGIN, Ph.D., Assistant Professor of Engineering
RICHARD F. FORD, Ph.D., Assistant Professor of Biology
AVERY H. GALLUP, Ph.D., Professor of Botany
WILLIAM E. HAZEN, Ph.D., Associate Professor of Biology
FRANCIS J. HOWARD, Ph.D., Assistant Professor of Physical Science
EDWARD W. HUFFMAN, Ph.D., Professor of Zoology
DON HUNSAKER, II, Ph.D., Professor of Zoology
WALTER D. JONES, Ph.D., Assistant Professor of Chemistry
JAMES H. MATHEWSON, Ph.D., Assistant Professor of Chemistry
WILLIAM McBLAIR, Ph.D., Associate Professor of Biology
NORMAN McLEAN, Ph.D., Assistant Professor of Zoology
CHARLES MORGAN, M.S., Professor of Engineering
IRAJ NOORANY, Ph.D., Assistant Professor of Engineering
FREDERICK T. QUIETT, M.S., Professor of Engineering
HERSCHEL SNODGRASS, Ph.D., Assistant Professor of Physics
FRANK E. STRATTON, Ph.D., Assistant Professor of Engineering
WILFRED J. WILSON, Ph.D., Associate Professor of Zoology

Degrees Offered:

- Bachelor of Arts and Bachelor of Science in Biology, Botany, Chemistry, Geology, Physics, and Zoology.
- Bachelor of Science in Engineering
- Master of Arts and Master of Science in Biology, Chemistry, and Physics. (M.A. and M.S. in Zoology planned for the near future.)
- Master of Science in Civil Engineering, Electrical Engineering, Mechanical Engineering, Aerospace Engineering, and Geology.
- Ph.D. in Chemistry, offered jointly with the University of California, San Diego (Doctoral programs in Biology and other science departments are planned for the near future).

Courses Offered:

Biology

Undergraduate Courses

Biology 110 ECOLOGY
Staff

Relationships between organisms and the environment; field study in local marine, fresh water, mountain, chaparral and desert habitats.

Biology 111 AQUATIC BIOLOGY
Crawford

Biological, chemical and physical considerations of inland waters.

Biology 112 FISHERIES BIOLOGY
Farris

Theory and practices of fishery management. Life histories and biology of important game and food fishes.

Biology 113 BIOLOGICAL OCEANOGRAPHY
Darby, Ford

Environmental relationships of benthic and pelagic marine organisms.

Biology 114 ADVANCED ECOLOGY
Staff

A detailed examination of ecological processes at the individual, population or community level.

Biology 175 STATISTICAL METHODS IN BIOLOGY
Staff

Application of statistical techniques to biological data.

Biology 191 SENIOR INVESTIGATION AND REPORT IN ECOLOGY
Staff

Investigation and reports on current ecological literature.

Biology 198 METHODS OF INVESTIGATION
Staff

Biology 199 SPECIAL STUDY
Staff

Individual Study

Graduate Courses

Biology 231 SEMINAR IN ETHOLOGY
Hunsaker

Biology 240 SEMINAR IN ECOLOGY
Staff

(Seminar topics include plankton and benthic ecology)

Biology 291 INVESTIGATION AND REPORT
Staff

Analysis and research techniques in biology.

Biology 298 SPECIAL STUDY
Staff

Individual study.

Biology 299 THESIS
Staff

Botany

Undergraduate Courses

Botany 101 PHYCOLOGY
Gallup

Morphology, phylogenetic relationships and biology of the algae.

Botany 190 SENIOR INVESTIGATION AND REPORT
Staff

Selection and design of individual projects; oral and written reports.

Botany 199 SPECIAL STUDY
Staff

Individual Study.

Graduate Courses

Botany 200 SEMINAR
Staff

An intensive study in advanced botany.

Botany 298 SPECIAL STUDY
Staff

Individual study.

Botany 299 THESIS
Staff

Chemistry

Undergraduate Courses

Chemistry 198 SENIOR PROJECT
Staff

An individual investigation and report on a problem.

Chemistry 199 SPECIAL STUDY
Staff

Individual study.

### Graduate Courses

Chemistry 200 SEMINAR
Staff

An intensive study in advanced chemistry.

Chemistry 291 RESEARCH SEMINAR
Staff

Discussions on current chemical research by students, faculty, and visiting scientists.

Chemistry 297 RESEARCH
Staff

Chemistry 298 SPECIAL STUDY
Staff

Individual study.

Chemistry 299 THESIS
Staff

## Engineering

Civil Engineering 235 WATER QUALITY ENGINEERING
Stratton

Development of water quality criteria. Survey of current methods of water treatment, wastewater treatment and water renovation. Economic considerations of water quality management.

Civil Engineering 236 WATER QUALITY PROCESSES I.
Stratton

Theoretical and laboratory study of the chemical and microbiological processes which govern modern water and wastewater treatment.

Civil Engineering 237 WATER QUALITY PROCESSES II.
Stratton

Laboratory and pilot plant studies involving the application of physical, chemical and biological processes to the treatment of water, wastewater and industrial wastes.

Civil Engineering 283 SEMINAR IN HYDRAULIC ENGINEERING
Staff

An intensive study in hydraulic engineering.

Civil Engineering 284 SEMINAR IN SANITARY ENGINEERING
Staff

An intensive study in sanitary engineering.

## Geology

### Undergraduate Courses

Geology 198 SENIOR REPORT
Staff

Individual research project, involving field work in a selected field of geology.

Geology 199 SPECIAL STUDY
Staff

Individual study in field, library, laboratory or museum work.

### Graduate Courses

Geology 200 SEMINAR
Staff

An intensive study in advanced geology.

Geology 298 SPECIAL STUDY
Staff

Individual study.

Geology 299 THESIS
Staff

## Oceanography

### Undergraduate Courses

Oceanography 100 THE OCEANS
Howard, McBlair

Biological and physical aspects of the oceans and their significance to man; problems of modern oceanography.

## Physical Science

### Undergraduate Courses

Physical Science 110 PHYSICAL OCEANOGRAPHY
Howard

Introduction to physical oceanography.

Physical Science 170 THEORETICAL OCEANOGRAPHY
Staff

The application of hydrodynamics and thermodynamics to the system composed of the atmosphere and the oceans.

## Physics

### Undergraduate Courses

Physics 198 SENIOR RESEARCH
Staff

Selection and design of individual research project.

Physics 199 SPECIAL STUDY
Staff

Individual study.

Graduate Courses

Physics 200 SEMINAR
Staff

An intensive study in advanced physics.

Physics 297 RESEARCH
Staff

Physics 298 SPECIAL STUDY Staff

Individual study.

Physics 299 THESIS
Staff

## Zoology

Undergraduate Courses

Zoology 112 MARINE INVERTEBRATES
Dexter, McLean, Wilson

Morphology, ecology, behavior and physiology of marine invertebrates.

Zoology 115 ICHTHYOLOGY
Crawford

Evolution, interrelationships, structure, identification, habits and ecology of fishes.

Zoology 150 MARINE BIOLOGY
Dexter, Huffman, McLean

General marine biology for non-majors. Studies of the morphology, physiology and behavior of marine organisms.

Zoology 191 SENIOR INVESTIGATION AND REPORT
Staff

Zoology 198 METHODS OF INVESTIGATION
Staff

Zoology 199 SPECIAL STUDY
Staff

Selection and design of original research in zoology.

Graduate Courses

Zoology 200 SEMINAR IN MARINE INVERTEBRATES
Dexter, McLean, Wilson

Zoology 201 SEMINAR IN MARINE ZOOLOGY
Dexter, McLean, Wilson

Zoology 212 ADVANCED MARINE INVERTEBRATES
Dexter, McLean, Wilson

Selected topics in marine invertebrate zoology.

Zoology 291 ANALYSIS AND RESEARCH TECHNIQUES IN ZOOLOGY
Staff

Zoology 298 SPECIAL STUDY
Staff

Individual study.

Zoology 299 THESIS
Staff

Persons to be contacted for further information:

Dr. James E. Crouch, Chairman
Division of Life Sciences
San Diego State College
San Diego, California 92115

Martin P. Capp, Dean
School of Engineering
San Diego State College
San Diego, California 92115

Dr. Dudley H. Robinson, Chairman
Division of Physical Sciences
San Diego State College
San Diego, California 92115

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## SAN JOSE STATE COLLEGE
San Jose, California 95114

### SCHOOL OF NATURAL SCIENCES

An interdisciplinary approach to oceanography is emphasized in the undergraduate and graduate training programs. At the undergraduate level, training is done through oceanography options for each regular science major, e.g. chemistry, geology, biology, etc. At the graduate level, training is tailored to the student for the Master's Degree; theses are required. A doctorate program is contemplated for the future.

Construction of a third science building with approximately 200,000 square feet of floor space will be completed this summer (1967). Facilities are included for research and teaching in oceanography at the undergraduate and Master's degree levels. Special facilities include: seashore laboratories at Moss Landing (Monterey Bay) (see under special heading), separate map room with complete coverage of ocean floor, electron microscope laboratory, collection of marine samples from world wide localities, complete sedimentation laboratory, and complete equipment for x-ray studies.

The main staff interest resides in shallow water oceanography and bay studies (San Francisco Bay, Monterey Bay, and adjacent ones). Ample vessel facilities are available for this type of research.

Instructional Staff:

ROBERT E. ARNAL, Ph.D., Professor, General Oceanography and Geological Oceanography
JOHN P. BROOKE, Ph.D., Assistant Professor, Geophysics and Geochemistry of Clays
NORMAN H. DOLLOFF, Ph.D., Professor, Geochemistry of Marine Sediments
JOHN P. HARVILLE, Ph.D., Professor, Fisheries and Marine Biology

PAULINE McMASTER, M.A., Associate Professor, Invertebrates and Marine Biology
ROBERT READ, M.S., Associate Professor, Meteorological Oceanography
CALVIN STEVENS, Ph.D., Assistant Professor, Fossil and Living Marine Microorganisms
ARTHUR D. STUMP, Ph.D., Assistant Professor, Chemical and Physical Oceanography

Degrees Offered:

Bachelor of Science with option in Oceanography
Master of Science (thesis required)

Students may specialize in any of the following fields: Geophysics, Geochemistry, Geological, Chemical, or Biological Oceanography.

Courses Offered:

All specialized courses are upper division and graduate courses.

Geol. 129 GENERAL OCEANOGRAPHY
Arnal

A study of the chemical and physical characteristics of sea water; distribution of ocean currents; geology of the ocean floor and study of the organisms of the sea.

Geol. 111 GEOPHYSICS
Brooke

An introduction to gravimetric, magnetic, seismic, electrical and electromagnetic surveys. Physical and geological principles, field techniques and case histories will be discussed.

Geol. 115 GEOCHEMISTRY
Dolloff

Application of principles, laws and techniques of chemistry to the solution of geological problems. Distribution of elements.

Geol. 113 MICROPALEONTOLOGY
Stevens

A study of living and fossil microorganisms, especially foraminifera, with emphasis on environmental relationships.

Geol. 141 GEOLOGICAL OCEANOGRAPHY
Arnal

A study of the structure, physiography and sediments of the sea bottom and shorelines.

Geol. 142 MARINE BIOGENIC SEDIMENTS
Arnal

Nature, composition and distribution of the sediment of the world ocean as they are affected by organisms.

Geol. 143 THE MARGIN OF THE OCEANS
Arnal

Nature, structure and economic potential of that portion of the ocean floor and subfloor located between the deep sea basins and the shoreline.

Zool. 100 MARINE INVERTEBRATE ZOOLOGY
McMaster

Study of adaptations and responses of invertebrate animals to their marine and estuarine habitats. Interrelationships of organisms within these environments

Biol. 141 BIOLOGICAL OCEANOGRAPHY
McMaster

Biological components of the sea, biological interactions, processes controlling composition distribution of organisms. Methodology.

Biol. 160 MARINE ECOLOGY
Harville

Exploration of the physical parameters of marine, estuarine and freshwater environments. Ecological and physiological responses to limiting factors in these environments.

Chem. 141 CHEMICAL OCEANOGRAPHY
Stump

Chemistry of the ocean processes for understanding the geochemical and biogeochemical phenomena of the ocean. Emphasis on chemical systems, reactions sites, oceanic radioactivity and the distribution of nuclides.

Phys. 141 PHYSICAL OCEANOGRAPHY
Stump

Study of physical parameters controlling oceanographic processes and phenomena--temperature, salinity, density and pressure fields. The dynamics of circulation turnover and mixing processes will be included.

Meteo. 135 METEOROLOGY OF THE OCEANS
Read

Energy exchange between the oceans and the atmosphere: distribution of temperature heat transport by ocean currents; relationship of wind waves and swell.

Persons to be contacted for further information:

Dr. Robert E. Arnal (for physical sciences)
Geology Department
San Jose State College
San Jose, California 95114

Dr. John Harville (for biological sciences)
Biology Department
San Jose State College
San Jose, California 95114

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## SCRIPPS INSTITUTION OF OCEANOGRAPHY
La Jolla, California 92038

Since 1912 the Scripps Institution of Oceanography has been a unit of the University of California. Now part of the University of California San Diego campus, the nine buildings of the Scripps Institution are clustered on the ocean shore north of the center of La Jolla, a suburb of San Diego. The SIO Library, a unit of the University Library, contains more than 65,000 volumes, 87,000 reports and reprints, 3,000 serials, and a large collection of charts.

Special Facilities:

Radio station WWD, operated by the U.S. Bureau of Commercial Fisheries
The Scripps Pier, 1,000 feet long, housing apparatus for a number of serial oceanographic observations, and used as a landing place for skiffs
The salt-water system providing clean sea water to the aquarium and biological laboratories.
An underwater area for research and collecting offshore from the Institution
Deep-sea sediment cores from several thousand widely scattered localities in the world ocean
Original echograms along several hundred thousand miles of ships' tracks in the Pacific
Carbon-14 and tritium laboratories
An oceanographic data archive of some half a million bathythermograph (BT) observations
An electron microprobe laboratory
Six mass spectrographs
Several thousand samples of sea water from the world oceans
An electron microscope laboratory
The Scripps fish collection of more than 250,000 specimens of some 2,000 species of marine fish
Unsorted oceanic samples of plankton
Scripps scientists have access to the University's Computer Center

The Institution operates nine ships specially fitted for oceanographic research.

ALEXANDER AGASSIZ
ARGO
FLIP (Stable research platform)
ALPHA HELIX
HORIZON
OCONOSTOTA
E. B. SCRIPPS
T-441
WASHINGTON

Instructional Staff:

ROBERT S. ARTHUR, Ph.D., Professor of Oceanography
CHARLES S. COX, Ph.D., Professor of Oceanography
EDWARD W. FAGER, Ph.D., D.Phil., Professor of Marine Ecology
DOUGLAS L. INMAN, Ph.D., Professor of Oceanography
JOHN D. ISAACS, B.S., Professor of Oceanography
FRED B. PHLEGER, Ph.D., Professor of Oceanography
MILNER B. SCHAEFER, Ph.D., Professor of Oceanography (Director of the Institute of Marine Resources)
FRED N. SPIESS, Ph.D., Professor of Oceanography (Director of the Marine Physical Laboratory, Associate Director of Scripps Institution of Oceanography)
WARREN S. WOOSTER, Ph.D., Professor of Oceanography (Chairman of the Department)
MICHAEL LONGUET HIGGINS, Ph.D., Senior Lecturer
CHARLES D. KEELING, Ph.D., Associate Professor of Oceanography
JOHN A. McGOWAN, Ph.D., Associate Professor of Oceanography
EDWARD L. WINTERER, Ph.D., Associate Professor of Geology
JAMES T. ENRIGHT, Ph.D., Assistant Professor of Oceanography
MYRL C. HENDERSHOTT, Ph.D., Assistant Professor of Oceanography
FERREN MacINTYRE, Ph.D., Assistant Professor of Oceanography
WILLIAM A. NEWMAN, Ph.D., Assistant Professor of Oceanography
MELVIN N. PETERSON, Ph.D., Associate Professor of Oceanography
MICHAEL M. MULLIN, Ph.D., Assistant Professor of Oceanography
RUDOLPH W. PREISENDORFER, Ph.D., Research Mathematician, Lecturer
JOHN D. H. STRICKLAND, Ph.D., Research Oceanographer and Lecturer
TJEERD H. van ANDEL, Ph.D., Research Geologist, Lecturer
JOSEPH L. REID, JR., M.S., Research Oceanographer, Lecturer
JOSEPH R. CURRAY, Ph.D., Associate Research Geologist, Lecturer
WILLIAM R. RIEDEL, M.S., Associate Research Geologist, Lecturer
MILTON N. BRAMLETTE, Ph.D., Professor Emeritus
CARL H. ECKART, Ph.D., Professor of Geophysics
EDWARD D. GOLDBERG, Ph.D., Professor of Chemistry
FRANCIS T. HAXO, Ph.D., Professor of Biology
CARL L. HUBBS, Ph.D., Professor of Biology Emeritus
MARTIN W. JOHNSON, Ph.D., Professor of Marine Biology Emeritus
GEORGE E. McEWEN, Ph.D., Professor of Oceanography Emeritus
HENRY W. MENARD, Ph.D., Professor of Geology
WALTER H. MUNK, Ph.D., Professor of Geophysics
NORRIS W. RAKESTRAW, Ph.D., Professor of Chemistry Emeritus
ROGER REVELLE, Ph.D., D.Sc., Professor of Oceanography Emeritus
FRANCIS P. SHEPARD, Ph.D., Professor of Submarine Geology Emeritus

Degrees Offered:

Master's Degree in Oceanography

Because of limited facilities, the Department does not at the present time encourage students who wish to proceed only to the Master's Degree. Special arrangements can, however, be made if circumstances warrant it.

Doctor of Philosophy in Oceanography

Courses Offered:

Upper Division

110. INTRODUCTION TO PHYSICAL OCEANOGRAPHY
Wooster

Physical description of the sea, physical properties of sea water, methods and measurements with demonstration at sea, boundary processes, regional oceanography. Prerequisites: the mathematics and physics required for admission to the graduate curriculum in oceanography or consent of instructor.

111. MARINE GEOLOGY
Menard

Introduction to the geomorphology, sedimentation, stratigraphy, vulcanism, structural geology, and geologic history of the marine realm. Prerequisites: the physics and geology required for admission to the graduate curriculum in oceanography or consent of instructor.

112. BIOLOGICAL OCEANOGRAPHY - ENVIRONMENT AND ORGANISMS
McGowan, Mullin

An introduction to the biota and life zones of the open ocean; descriptions of the physical, chemical and biological factors of this environment; discussions of the influence of the factors on oceanic populations. Prerequisites: the biology and chemistry required for admission to the graduate curriculum in oceanography or consent of instructor.

112L. MARINE ORGANISMS
McGowan

Laboratory and discussion of the phylogeny; comparative morphology; life histories and taxonomy of marine organisms. Emphasis will be placed on planktonic groups. Prerequisites: consent of instructor and concurrent registration in Oceanography 112.

113. INTRODUCTION TO CHEMICAL OCEANOGRAPHY
Keeling

Chemical description of the sea; the distribution of chemical species in the world oceans and their relation to physical and biological processes. Prerequisites: the mathematics, physics and chemistry required for admission to the graduate curriculum in oceanography or consent of instructor.

118A-118B. STATISTICS
Fager

Methods of statistical analysis, including both parametric and nonparametric procedures; sampling and design of experiments, with emphasis on those procedures particularly useful in marine studies. Prerequisite: the mathematics required for admission to the graduate curriculum in oceanography or consent of instructor.

199. SPECIAL STUDIES
Staff

Prerequisite: consent of instructor.

Graduate

210. INTRODUCTION TO DYNAMICAL OCEANOGRAPHY
Arthur, Cox

Mechanics of fluids on a rotating earth; Navier-Stokes equations, boundary layer phenomena, turbulent flow and wave motion with oceanographic applications. Prerequisites: Oceanography 110 and consent of instructor.

211. INTRODUCTION TO WIND WAVES
Cox

Wind waves, swell and surf; propagation of energy, the spectrum of waves; methods of observation; long waves, internal waves. Prerequisite: Oceanography 210 or consent of instructor.

212. BIOLOGICAL OCEANOGRAPHY - PROCESSES AND EVENTS
McGowan, Mullin

An analysis of the concepts and theories used to explain the biological events observed in the ocean. Prerequisites: Oceanography 110, 112 or consent of instructor.

212L. LABORATORY IN BIOLOGICAL PRODUCTIVITY
Mullin

Introduction to techniques, especially those usable at sea, for measuring the standing crop and productivity of marine communities. Prerequisites: Oceanography 212 (may be taken concurrently) and consent of instructor.

213. CHEMICAL OCEANOGRAPHY
Keeling

Extension of the topics of Oceanography 113 and the chemistry of sea water with emphasis on thermodynamic considerations. Prerequisites: Oceanography 113 or consent of instructor.

214. MARINE SEDIMEMTS
van Andel, Peterson

Processes of sediment supply to the oceans; distribution, composition and genesis of marine sediments; marine sedimentary facies with special regard to sediments of the continental margins; implications for stratigraphy and historical geology; trends in sediment research. Prerequisite: consent of instructor.

215. MECHANICS OF MARINE SEDIMENTATION
Inman

Mechanics of sediment transportation by water, wind, waves and density flows; energetics of sediment transport. Prerequisites: Oceanography 210 or equivalent.

### 216. MARINE STRATIGRAPHY

Winterer, Riedel

Principles of stratigraphy as applied to marine environments; laboratory study and interpretation of microfossils in oceanic sediments. Prerequisites: Oceanography 111 or consent of instructor.

### 218A-218B. MARINE ECOLOGY

Fager

Single-species population dynamics and interspecific relationships in communities; theory, observation and interpretation. Behavior, environmental factors and productivity as they relate to the distribution and abundance of organisms. Prerequisite: Oceanography 112.

### 219. PHYSICAL OCEANOGRAPHY - GENERAL

Arthur

Dynamics of ocean currents, transport phenomena, turbulent processes and the air-sea boundary layer. Prerequisites: differential equations and consent of instructor.

### 220. SPECIAL TOPICS IN OCEANOGRAPHY

Staff

Within the next few years the following subjects will be covered: principles of oceanographic research systems, sound and light in the sea, comparative regional oceanography, advanced methods of fisheries research, numerical analysis, studies of turbulence and waves.

### 221. OCEAN WAVES

Cox

Mechanisms of generation, transformations of energy and momentum in surface and internal waves, effects of Earth rotation on waves. Prerequisite: Oceanography 211 or consent of instructor.

### 222A-222B. HYDRODYNAMICS

Eckart

Applications of hydrodynamics to the motion of stratified fluids, such as the atmosphere and oceans. Internal waves, steady currents and related phenomena. Prerequisite: consent of instructor.

### 223. WIND-DRIVEN OCEAN CIRCULATION

Arthur

Wind currents, theories of ocean circulation, boundary currents. Prerequisites: Oceanography 219 and consent of instructon

### 226A-226B. ADVANCED INVERTEBRATE ZOOLOGY

Newman

The natural history, zoogeography, taxonomy and phylogeny of selected invertebrate groups. Emphasis will be on the broader aspects of current research. Two special problems will be undertaken; original problems will be encouraged. Prerequisites: Oceanography 112, 112L, or consent of instructor.

### 228. POPULATION DYNAMICS

Schaefer

Theories and mathematical models concerning growth and dynamics of single-species populations, interspecific competition, predatory-prey relationships, dynamics of exploited marine populations and other animal associations. Prerequisites: Oceanography 218A or consent of instructor.

### 229. OCEANIC ZOOGEOGRAPHY

McGowan

The patterns of distribution and abundance of oceanic organisms, the nature of oceanic habitats, the relation of zoogeography to paleoceanography; lectures, student reports and discussions. Prerequisites: Oceanography 212 (Oceanography 111 is desirable).

### 230. SEDIMENTARY PETROLOGY

Winterer

Characteristics and origin of sediments and sedimentary rocks. Prerequisite: consent of instructor.

### 231. MINERALS AND MINERAL ASSEMBLAGES OF SEDIMENTS

Peterson

Origin and distribution of minerals and mineral assemblages of sediments; important mineral groups, clays, zeolites, feldspars, etc., considered by crystal structure and composition; directed toward oceanic sediments; laboratory on instrumental methods, x-ray diffractometry and spectroscopy. Prerequisite: consent of instructor.

### 234A-234B. MARINE MICROPALEONTOLOGY

Phleger

Introduction to the ecology of Foraminifera and with applications to problems of oceanography and paleoceanography. Prerequisites: for Oceanography 234A: Oceanography 111 or consent of instructor; for Oceanography 234B: Oceanography 234A.

### 235. SEDIMENTARY PROCESSES

Inman

Application of principles of sedimentary mechanics to selected environments, including the littoral; the transportation of sediment and the formation of sedimentary structures by waves and currents; methods of measurement. Prerequisites: Oceanography 215 or consent of instructor.

### 250. SEMINAR IN OCEANOGRAPHY

Staff

### 251A-251B. PROBLEMS IN GENERAL AND PHYSICAL OCEANOGRAPHY (SEMINAR)

Isaacs

Presentation of reports, review of literature, and discussion of various regions and aspects of the ocean, oceanography and related fields.

253. PROBLEMS IN BIOLOGICAL OCEANOGRAPHY (SEMINAR)

Fager

Presentation of reports, review of literature and discussion of current research in biological oceanography.

255. PROBLEMS IN MARINE GEOLOGY (SEMINAR)

Staff

Origin and structure of ocean basins and continental margins and their physiographic features; origin, distribution, interpretation and methods of study of marine sediments.

280. OCEANOGRAPHY FIELD COURSE

Staff

Methods of measurement, observation and sampling used at sea; oceanic cruise dealing with problems of current interest; analysis and interpretation of results with a report. Prerequisites: Oceanography 110, 111, 112, and 113.

299. RESEARCH

Staff

Research in one or more of the oceanographic sciences.

Person to be contacted for further information:

Chairman, Department of Marine Biology
Scripps Institution of Oceanography
La Jolla, California 92038

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## UNIVERSITY OF CALIFORNIA
Davis, California 95616

### DEPARTMENT OF GEOLOGY

At the University of California's newly completed (July, 1966) 25,000 square foot marine facility at Bodega Bay, the Laboratory of Marine Geology and Paleoecology has been established to support the Department of Geology's rapidly expanding research and teaching program in oceanography. The Bodega Marine Laboratory, well-equipped with analytical instrumentation and capable of broad-scale research support, is located on a 285 acre biological preserve 50 miles north of San Francisco.

Instructional Staff:

JAMES W. VALENTINE, Ph.D., Associate Professor, Paleobiology and Paleoecology
THOMAS W. TODD, Ph.D., Assistant Professor, Geological Oceanography
JERE H. LIPPS, Ph.D., Assistant Professor, Paleontology of Planktonic Organisms

Degrees Offered:

The Department of Geology, University of California, Davis offers the Bachelor of Arts, Bachelor of Science, Master of Science, and Doctor of Philosophy degrees. Candidates for graduate degrees who are interested in oceanography may pursue thesis research in the fields of marine ecology, paleontology, paleoecology, marine sedimentation, or sedimentary petrology.

Undergraduate Courses

Upper Division

S119. MARINE GEOLOGY AND PALEOECOLOGY OF THE CONTINENTAL SHELF

Todd, Valentine, Lipps

A 6-week upper division undergraduate summer field and laboratory course involving examination of physical and biological aspects of the modern marine environment, and of the geology and paleontology of marine sedimentary rock of the Pacific Coast. Emphasis is placed on study of processes of sedimentation and on characteristics of biological communities.

198. DIRECTED GROUP STUDY

Staff

199. SPECIAL STUDY FOR ADVANCED UNDERGRADUATES

Staff

Graduate Courses

S219. SPECIAL STUDIES IN MARINE GEOLOGY AND PALEOECOLOGY

Valentine, Todd

A 4 to 6-week graduate summer problems course involving field and laboratory investigation of subjects within the marine realm selected by the student, with the advice of the Laboratory faculty.

298. GROUP STUDY

Staff

299. RESEARCH

Staff

Person to be contacted for further information:

Dr. Thomas W. Todd
Department of Geology
University of California
Davis, California 95616

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## THE UNIVERSITY OF SOUTHERN CALIFORNIA

Los Angeles, California 90007

In addition to the usual research laboratory facilities, the University of Southern California has the outstanding Hancock Library of Biology and Oceanography, consisting of over 85,000 volumes and 100,000 reprints and pamphlets and the marine biological collections of the Allan Hancock Foundation. The University's 110-foot oceanographic vessel, VELERO IV, is used in many of the marine sciences programs. A 28-foot twin engined cruiser, AHOYOHA III, is used for some nearshore and intermediate depth work.

Biological research includes ecologic, physiologic, biogeographic, and systematic studies of marine animals and plants. Field investigations are in progress off the Southern California Coast, and in the Arctic and Antarctic Oceans.

Geological research is concentrated in the shallow waters and on sediments of the continental margins with emphasis on quantitative studies of chemical, physical, and biological parameters. Paleoecologic studies are in progress on microfaunal communities important in the fossil record.

The Santa Catalina Island Marine Biological Laboratory, with facilities for about 20 persons engaged in research and 32 students taking graduate courses, will be completed by the fall of 1967. The laboratory will be located at Fisherman Cove in the Isthmus area of the Island, which is located approximately 20 miles from Los Angeles. The laboratory will be available to visiting investigators and students from the United States and abroad.

Instructional Staff:

Department of Biological Sciences

PAUL R. SAUNDERS, Ph.D., Professor; Director, Marine Sciences Program
LESLIE A. CHAMBERS, Ph.D., Professor; Director of Allan Hancock Foundation
JOHN GARTH, Ph.D., Professor
OLGA HARTMAN, Ph.D., Professor
JOHN L. MOHR, Ph.D., Professor
JAY M. SAVAGE, Ph.D., Professor
RICHARD B. TIBBY, Ph.D., Professor
GERALD J. BAKUS, Ph.D., Associate Professor
BASIL G. NAFPAKTITIS, Assistant Professor
RUSSEL L. ZIMMER, Ph.D., Assistant Professor

Department of Geology

ORVILLE L. BANDY, Ph.D., Professor
DONN S. GORSLINE, Ph.D., Professor
ROBERT H. OSBORNE, Ph.D., Associate Professor

Degrees Offered:

Master of Science and Doctor of Philosophy in Biology, with specialization in Marine Biology

Master of Arts, Master of Science, and Doctor of Philosophy in Geology, with specialization in Oceanography

Courses Offered:

Department of Biological Sciences

Undergraduate Courses

None

Graduate Courses

509abL INVERTEBRATE ZOOLOGY — Zimmer

Living animals, particularly marine invertebrates; habitats, including mud flats, sandy beaches, rocky shores.

531 SEMINAR IN MARINE INVERTEBRATE ZOOLOGY — Staff

533 SEMINAR IN BIOSYSTEMATICS — Staff

542L ICHTHYOLOGY — Nafpaktitis

Evolution, systematics, ecology, behavior, life history, and distribution of living fishes, including the basic principles of fisheries biology.

546L CRUSTACEAN BIOLOGY — Garth

Systematics, morphology, physiology, ecology, life history, distribution, behavior, and experimental use of living crustacea.

547L MALACOLOGY — McLean

Systematics, morphology, physiology, ecology and distribution of mollusks.

551 BIOSYSTEMATICS — Savage

Scope and significance of systematic biology; basis in organic evolution; characteristics and origins of populations, species and higher categories; experimental approaches to systematic problems; interrelations with other fields.

573L MARINE ECOLOGY — Bakus

Interrelationships between marine populations and communities and their environments.

### 574L MARINE PLANKTON ECOLOGY

Composition, population dynamics, productivity, distribution, migration, and energy cycles in phyto- and zooplankton communities.

### 590 DIRECTED RESEARCH

Staff

Original investigation of a selected problem in biology; requires preparation of a formal paper to be evaluated by the Guidance Committee for the M.S. degree. Not more than one semester's credit may be offered in satisfaction of graduate degree requirements.

### 790 RESEARCH

Staff

Independent investigation of a problem in biology.

## Department of Geology

## Undergraduate Courses

### 107L ELEMENTS OF OCEANOGRAPHY

Gorsline

Physical, chemical and geological character of the oceans and ocean basins. Origin of the oceans. Ocean processes and agents. Economic value of the oceans.

### 440L GEOPHYSICS

Christensen

Principles and analysis of data of earth gravity, magnetism, isostasy, seismology; internal constitution of the Earth; geochronology; heat flow and temperature of the Earth; mechanical properties of rocks.

### 460L DESCRIPTIVE GEOCHEMISTRY

Taylor

Geochemical structure of the Earth; distribution and geochemical behavior of elements in the lithosphere and other geochemical spheres.

### 478L MICROPALEONTOLOGY

Bandy

Microscopic fossils, especially Foraminifera, their classification, the common genera, morphology, evolutionary trends; laboratory and field techniques.

## Graduate Courses

### 500L MARINE PALEOECOLOGY

Bandy

Principles of marine paleoecology; interrelationships between marine organisms and their environment in geologic time.

### 510 SEDIMENTARY PROCESSES

Gorsline

Origin, transportation, deposition of sediments; conditions modifying sedimentary processes; environments of sedimentation; interpretation of former climatic and physiographic conditions.

### 511L SEDIMENTARY TECHNIQUES

Gorsline

Collection of samples; analyses for grain size; gross fractionation methods; description and interpretation of sediments.

### 512 OCEANOGRAPHY

Gorsline

Chemical and physical properties of sea water; movement of water masses; relation of water characteristics to meteorological factors; relations of marine organisms to water composition.

### 514 MARINE GEOLOGY

Gorsline

Origin of ocean basins; characteristics of rock underlying the ocean floor; development of island arcs, continental shelves, continental slopes, submarine canyons, coral reefs.

### 519L SEDIMENTARY PETROGRAPHY

Merriam

Application of the microscope to the study of sediments.

### 531 GEOTECTONICS

Davis

Distribution of orogeny in space and time; origin and development of major structure units: geosynclines, mountain belts; relationship between orogenesis and igneous activity.

### 533 SEMINAR IN STRATIGRAPHIC METHODS

Osborne

Physical and paleontological analysis applied to accumulation and correlation of rock successions. Original project.

### 540L ADVANCED GEOPHYSICS

Christensen

Physics of the Earth's interior; recent advances in geophysics; review of literature.

### 560L ADVANCED GEOCHEMISTRY SEMINAR

Taylor

Problems and recent advances in geochemistry; analytical techniques.

578L ADVANCED MICROPALEONTOLOGY
Bandy

Microfaunal correlations; stratigraphic sequence of microfaunas; phylogenesis of foraminifera; paleoecology; applied micropaleontology; reports on microfaunas from local and foreign strata.

590 SPECIAL PROBLEMS
Staff

600 ADVANCED SEMINAR ON SPECIAL TOPICS IN EARTH SCIENCES
Staff

Joint faculty and advanced graduate student seminars on topics of specific interest. Review of literature.

790ab RESEARCH
Staff

Intensive study of specific problems under the direction of a member of committee of the staff in geology.

Persons to be contacted for further information:

Dr. Paul R. Saunders (Marine biology and
and sciences program)
Professor of Biology and
Director, Marine Sciences Program
University of Southern California
University Park
Los Angeles, California 90007

Dr. Donn S. Gorsline (Marine geology)
Department of Geology
University of Southern California
University Park
Los Angeles, California 90007

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## UNIVERSITY OF BRIDGEPORT
Bridgeport, Connecticut 06602

One small boat is available for use in the Sound. Laboratory facilities are in the Department of Biology.

With the U.S. Naval Oceanographic Office, the University runs a cooperative program which leads to a B.S. in one of the basic sciences (mathematics, chemistry, biology, and physics) and offers students an opportunity to work at sea as civil service employees at GS grades 2-5.

Instructional Staff:

MICHAEL E. SOMERS, Ph.D., Assistant Professor, Biology

Degrees Offered:

Master of Science in Biology

Courses Offered:

Graduate Courses

Biology 516-517 MARINE ECOLOGY I AND II

Field course centered around the ecological distribution of the fauna of the littoral zones of adjacent Long Island Sound. Summer only.

Person to be contacted for further information:

Dr. Francis E. Dolan
Chairman, Department of Biology
College of Arts and Sciences
University of Bridgeport
Bridgeport, Connecticut 06602

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## UNIVERSITY OF CONNECTICUT
Storrs, Connecticut 6268

The Marine Research Laboratory of the University of Connecticut is located at the mouth of the Mystic River in Noank, Connecticut. The main laboratory building is a two-story brick structure, 52' x 62', and has a concrete deck leading to a T-shaped dock, 125' long and 50' parallel to the channel. The building contains eight laboratory rooms, darkroom, histological technique room, balance room, library, shop and storerooms. Two additional laboratory rooms, added to the main building are equipped for microbiology and ecology. All basic utilities, including salt water, are supplied to all laboratories. The laboratories contain chemical, radiobiological, climatological and ecological equipment.

A 65' former T-boat, a 44' and a 41' cabin cruiser, two 25' open launches and several skiffs are available for research work. An assortment of biological and hydrographic collecting gear is used.

Instructional Staff:

JOHN S. RANKIN, JR., Ph.D., Professor, Zoology and Director, Marine Research Laboratory
JOHN D. BUCK, Ph.D., Assistant Professor of Bacteriology
BENJAMIN J. COSENZA, Ph.D., Assistant Professor of Bacteriology
SUNG YEN FENG, Ph.D., Assistant Professor of Zoology and Entomology
DAVID FRANZ, Ph.D., Assistant Professor of Zoology and Entomology
LARRY FRANKEL, Ph.D., Associate Professor of Geology
HUGO THOMAS, Ph.D., Assistant Professor of Geology
WILLIAM A. LUND, JR., Ph.D., Assistant Professor of Zoology
GEORGE R. RUMNEY, Ph.D., Associate Professor of Geography
DONALD M. SKAUEN, Ph.D., Professor of Pharmacy
FRANCIS R. TRAINOR, Ph.D., Professor of Botany

### Degrees Offered:

Master of Science and Doctor of Philosophy in various departments of the University with specialization in marine science.

### Courses Offered:

No formal courses are yet given at Noank. When additional facilities are available, summer graduate courses in marine ecology, bacteriology and radioecology will be introduced. However, several departments on the main campus offer courses involving marine studies, and make use of the Marine Research Laboratory for field work. The following are pertinent.

### Bacteriology

265. MARINE MICROBIOLOGY
Buck

A general introduction to the distribution, ecology and activities of marine microorganisms, particularly the bacteria.

300. SPECIAL PROBLEMS IN BACTERIOLOGY
Staff

For undergraduates who have demonstrated special aptitude in bacteriology and for graduate students in bacteriology or related fields.

311. SEMINAR
Staff

Consists of readings, reports and roundtable discussions and is planned for graduate and advanced students in bacteriology or related subjects.

321.-322. BACTERIAL PHYSIOLOGY I-II
Cosenza

A study of cell morphology, multiplication and death rates, and enzymatic activities of representative bacterial species.

### Botany

281. INTRODUCTORY PHYCOLOGY
Trainer

A survey of the major groups of algae. Students have the opportunity to collect, culture and identify both freshwater and marine forms in field trips and laboratory exercises.

381. ADVANCED PHYCOLOGY
Ziegler

369. APPLICATIONS OF ISOTOPIC TRACERS TO BIOLOGICAL RESEARCH
Koontz, Wetherell

The use of radioactive isotopes in biological research with practice in handling the material, including radiochromatographic analysis and autoradiographic techniques.

### Civil Engineering

260. WATER AND SEWERAGE TREATMENT
Prior, Widmer

Physical, chemical and biological principles of the treatment of water, sewerage and industrial wastes; design, layout and operation of purification and treatment works; state and federal regulatory standards.

392. INDUSTRIAL WASTES
Prior, Widmer

Origin and characteristics of industrial wastes; methods for solving industrial waste problems.

394.-395. WATER POLLUTION
Widmer, Prior

The nature and causes of pollution; effects of pollution on the characteristics of fresh, estuarine and marine waters; survey methods; rationale of control.

### Geology and Geography

217. SEDIMENTATION
Thomas

Study of origin, transport, deposition and biogenesis of terrestrial, transitional and marine sediments.

263. METEOROLOGY AND CLIMATOLOGY
Rumney

An introduction to meteorology and physical and regional climatology. Field trips.

294. INTRODUCTORY OCEANOGRAPHY
Rumney

A physical geography of the sea. The character and distribution of bathymetric regions, physical and chemical properties and dynamic processes are presented, as well as the chief oceanographic environments and forms of life. Field trips to the shore are required.

310. MICROPALEONTOLOGY
Frankel

Anatomy, classification and evolution of Foraminifera, Ostracoda, and Bryozoa.

325. COASTAL CLIMATOLOGY
Rumney

A study of the unique qualities of atmospheric behavior identifying the transitional character of coastal climates between clearly continental and clearly marine climatic complexes.

ology

2. MALACOLOGY
Getz

Classification, phylogeny, ecology and zoogeography of molluscs; classification of molluscs of New England region.

7. MARINE ECOLOGY
Franz

The ocean as an environment, with special reference to shallow and estuarine regions; distribution of biota in relation to the physical and chemical environment. Field trips required.

9. MARINE ICHTHYOLOGY
Lund

Taxonomy and ecology of marine fishes.

0. ADVANCED INVERTEBRATE ZOOLOGY
Feng, Franz

A study of various invertebrate phyla, with particular reference to development, regeneration and phylogeny.

5. COMPARATIVE PHYSIOLOGY
Boettiger

Study of the design of physiological mechanisms found in the animal kingdom. Special attention is given to marine invertebrates.

rson to be contacted for further information:

Dr. John S. Rankin, Jr.
Director
University of Connecticut
Marine Research Laboratory
Noank, Connecticut 06340

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## YALE UNIVERSITY
New Haven, Connecticut 06520

NGHAM OCEANOGRAPHIC LABORATORY

The Bingham Oceanographic Laboratory longer exists as a separate entity. rmer research and teaching activities are ing continued under the auspices of related partments of Yale University.

structional Staff:

DANIEL MERRIMAN, Ph.D., Associate Professor of Biology
DONALD C. RHOADS, Ph.D., Assistant Professor of Geology
KARL K. TUREKIAN, Ph.D., Professor of Geology
THEODORE D. FOSTER, Ph.D., Assistant Professor of Geology

Degrees Offered:

None

Courses Offered:

Department of Biology

Biology 363b ECOLOGICAL PRINCIPLES IIb.
Merriman, Rhoads

(This course is also listed under Geology under Geology Department course offerings as Geology 163b.)

Department of Geology

Geology 182a MARINE GEOCHEMISTRY
Turekian

Geology 196a INTRODUCTION TO PHYSICAL OCEANOGRAPHY
Foster

Geology 197b DYNAMICAL OCEANOGRAPHY
Foster

Person to be contacted for further information:

Dr. Daniel Merriman
P.O. Box 2025
Yale Station
New Haven, Connecticut 06520

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## UNIVERSITY OF DELAWARE
Newark, Delaware 19711

DEPARTMENT OF BIOLOGICAL SCIENCES
Ocean-going and land-based research facilities.

The University of Delaware Marine Laboratories were established in 1951. The Laboratories form a part of the Department of Biological Sciences and now have major facilities at two centers. A Marine Biology Laboratory is on the University campus at Newark. Here the office of the laboratories' director, the reprint library, class room, and research facilities are organized to carry out laboratory research and the academic program of the Department.

The Field Station facilities are located adjacent to Lewes at the mouth of Delaware Bay. The Bayside Laboratory is located on a narrow strip of marshland topped by scattered sand dunes and bounded by Delaware Bay, Roosevelt Inlet and the Broadkill Creek. This unit was dedicated on June 9, 1956.

The Cape Henlopen Laboratory was acquired two years ago and is being developed for summer course work and research. Additional facilities have been acquired for an expanded research program with a total of 23,000 square feet. The Field Station holdings now total approximately 30 acres.

The R/V WOLVERINE, 46 ft. L.W.L., is equipped as a stern trawler capable of doing trawling, dredging and light coring, and has davits and booms for hydrographic and plankton collections. It is equipped with 110 AC, Loran, radar, berths and accommodations for five, two crew and three scientists. In addition there are several sixteen foot fiber glass outboard and smaller boats.

Instructional Staff:

W. ROBERT A. BAILEY, Ph.D., Professor of Biological Sciences
ROBERT L. BOORD, Ph.D., Assistant Professor of Biological Sciences
ARNOLD M. CLARK, Ph.D., Professor of Biological Sciences
FRANKLIN C. DAIBER, Ph.D., Associate Professor of Biological Sciences and Acting Director of the Marine Laboratories
F. CORTLAND HOUGHTON, M.A., Assistant Professor of Biological Sciences
JAMES B. KRAUSE, Ph.D., Associate Professor of Biological Sciences
PHILIP D. LUNGER, Ph.D., Assistant Professor of Biological Sciences
THOMAS D. MYERS, Ph.D., Assistant Professor of Biological Sciences
RICHARD A. NYSTROM, Ph.D., Assistant Professor of Biological Sciences
DOROTHY M. POWELSON, Ph.D., Associate Professor of Biological Sciences
MIRIAM S. SHANE, M.S., Assistant Professor of Biological Sciences
DAVID E. SHEPPARD, Ph.D., Assistant Professor of Biological Sciences
G. FRED SOMERS, Ph.D., Chairman and Professor of Biological Sciences
ROBERT W. STEGNER, Ph.D., Associate Professor of Biological Sciences
MARENES R. TRIPP, Ph.D., Associate Professor of Biological Sciences
HARRY W. WELLS, Ph.D., Assistant Professor of Biological Sciences
PHILIP S. WOODS, Ph.D., Associate Professor of Biological Sciences

Resident Staff - Bayside Laboratory

KENT S. PRICE, Ph.D., Assistant Professor of Biological Sciences and Field Station Director
DONALD L. MAURER, Ph.D., Assistant Professor of Biological Sciences
THEODORE P. RITCHIE, B.S., Oyster Biologist
RONAL W. SMITH, B.S., Resident Biologist
SIDNEY A. BENNETT, Boat Mate and Maintenance
MILTON W. COOPER, Resident Manager and Boat Captain
WILBERT E. HOCKER, Boat Engineer
EARL E. GREENHAUGH, Oyster Technician
JAMES E. DICKERSON, Oyster Technician

Degrees Offered:

Master of Arts and Master of Science in Biological Sciences. Doctor of Philosophy in Biological Sciences (Specialization in Marine Biology).

Courses Offered:

Undergraduate

Upper Division

B 623 PARASITOLOGY
Tripp

Animal parasites and vectors affecting man.

B 627 INTRODUCTION TO OCEANOGRAPHY
Myers

A descriptive survey of the physics, chemistry, biology, and geology of the world oceans.

B 628 MARINE BIOLOGY
Staff

Biology of the sea as exemplified by the marine environment, fauna and flora of Delaware. The course is given at the Field Station, Lewes, Delaware in the summer.

B 629 PHYSICAL OCEANOGRAPHY

A study of the ocean as a physico-chemical system.

B 630 ICHTHYOLOGY
Daiber

Biology of fishes including structure and function, reproduction, development, behavior, geographic distribution, and systematics.

B 634 INVERTEBRATE ZOOLOGY
Wells

Functional morphology, classification, and ecology of invertebrate animals, with special attention to local marine forms.

B 638 MARINE BOTANY

Biology of the aquatic flora of Delaware as found in the marine and brackish water environment. The course is given at the Field Station, Lewes, Delaware in the summer.

B 639 TOPICS IN MARINE ECOLOGY
Staff

Selected topics in marine ecology emphasizing field study of phenomena of Delaware Bay and the Atlantic Ocean.

B 671 SEROLOGY AND IMMUNOLOGY
Tripp

Basic concepts of antigens, antibodies, and serological reactions in biological systems.

Graduate

B 805 COMPARATIVE PHYSIOLOGY
Nystrom

Comparison of the reactions of different groups of animals to their environments with emphasis on mechanisms of adaptive significance; comparison of relationships between effector and integrative systems.

812 SPECIAL PROBLEMS
Staff

Original investigations in the biological sciences.

827 COLLOQUIUM IN MARINE SCIENCES
Staff

Discussion Group

828 MARINE INVERTEBRATES
Wells

Advanced training in methods for studying the biology of specific marine organisms.

860 ESTUARINE HYDROGRAPHY
Daiber

Analysis of estuarine systems: chemistry, physics, geology, and biology.

869 THESIS
Staff

870 RESEARCH
Staff

Independent and original research in the biological sciences. Seminar participation.

969 DOCTORAL DISSERTATION
Staff

epartment of Geology

eo 631 MARINE GEOLOGY
Kraft

Geology of the ocean basins and their continental margins: sedimentation within the marine environment and its uses in interpreting geologic history and paleoecology.

ersons to be contacted for further information:

Dr. Franklin C. Daiber
Acting Director
Marine Laboratories
University of Delaware
Newark, Delaware 19711

Dr. G. Fred Somers
Chairman
Department of Biological Sciences
University of Delaware
Newark, Delaware 19711

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## GRADUATE SCHOOL
## U.S. DEPARTMENT OF AGRICULTURE*
Washington, D. C. 20250

A Certified Statement of Accomplishment in Oceanography is granted to a student who has completed an organized program of courses in the field.

Requirements

1. 20 semester hours of credit with a grade of C or better in each of the following courses:

A. Required courses: (6 credits)

Biological Oceanography (2)
Geological Oceanography (2)
Physical Properties of Seawater (2)

B. Electives: (8 credits)

Applied Underwater Sound (2)
Biological Oceanography (2)
Dynamic Oceanography (2)
Marine Meteorology (2)
Ocean Surface Waves (2)
Principles of Underwater Sound (2)

C. 6 semester hours of credit in fields related to oceanography, including biology, chemistry, engineering, geography, geology, mathematics, and meteorology.

A student seeking this certified statement should consult with the Registrar and obtain approval of his proposed course of study early in his academic program. Equivalent courses will be accepted by transfer from other institutions. An applicant for this certified statement must file a transcript of his high school or college record before completion of his program.

Instructional Staff:

M. D. BURKHART, M.S., Oceanographer, U.S. Naval Oceanographic Office
RENE P. CUZON DU REST, M.S., Oceanographer, National Oceanographic Data Center
DAVID E. AMSTUTZ, M.S., Research Oceanographer, U.S. Naval Oceanographic Office
ANTHONY R. PICCIOLO, Ph.D., Head, Hydrobiology Branch, National Oceanographic Data Center
J. J. SCHULE, JR., B.A., Director, Oceanographic Prediction Division, U.S. Naval Oceanographic Office
JOSHUA I. TRACY, JR., Ph.D., Geologist, U.S. Geological Survey
MARTIN WEISS, Ph.D., Head, Geoscience Branch, National Oceanographic Data Center
ROBERT S. WINOKUR, B.S., Oceanographer, Acoustical Oceanography Branch, U.S. Naval Oceanographic Office

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* Not Accredited

Degrees Offered:

None

Courses Offered:

Undergraduate

### 5-360 GENERAL OCEANOGRAPHY

Amstutz

Characteristics of oceans and factors that control distribution of properties and of plants and animals. Biology, chemistry, geology, and physics of the oceans. Prerequisite: College courses in at least two of the physical or biological sciences.

Graduate

### 5-475 PRINCIPLES OF UNDERWATER SOUND

Winokur

Fundamental principles of acoustics and application of these principles to underwater sound. Transmission of sound in the sea, including refraction, reflection, scattering, attenuation, and fluctuation. Prerequisites: Calculus and college physics.

### 5-584 PHYSICAL PROPERTIES OF SEA WATER

Burns

Examination of physical principles governing properties of sea water. Comparison of these properties with those of pure water. Definition and *calculation of salinity and density.* Distribution of salinity, temperature and density.

### 5-655 OCEAN SURFACE WAVES

Schule

Measureable properties of ocean surface waves and the methods of observing and analysing ocean waves. Demonstration of waves solution to hydrodynamic equations. Discussion of various sea surface models including their assumptions, solutions, and practical applications. Problems of propagation of waves in dispersive medium. Examples of various forecasting techniques. Prerequisite: Calculus, or mathematics for oceanographers.

### 5-658 GEOLOGICAL OCEANOGRAPHY

Tracy, Weiss

Topography, composition processes of sedimentation, and geologic history of ocean basins, continental shelves, and coastal features. Prerequisite: Professional knowledge of geology or oceanography.

### 5-662 MARINE METEOROLOGY

Burkhart

Introduction to fundamental principles of marine meteorology with special emphasis upon problems of marine climatology and physical oceanography. Descriptive and synoptic meteorology. Air mass analysis. Boundary processes. Radiation. Climatic principles. Prerequisite: Professional knowledge of meteorology or oceanography.

### 5-664 DYNAMIC OCEANOGRAPHY

Schule

Introduction to principles of vector analysis. Development of principles of conservation of mass and momentum. Vector equations of motion. Hydrostatic equations and density-pressure-depth relationship. Various current equations. Principles of turbulence. Equation of mean motion. Various approaches to the problem of evaluation of eddy stress terms. Prerequisite: Physical properties of sea water or equivalent.

### 5-666 BIOLOGICAL OCEANOGRAPHY

Cuzon du Rest, Picciolo

First semester: Principles governing distribution and ecology of micro-organisms and plankton in the sea. Discussion of productivity, food chain, and related phenomena. Second semester: Distribution, ecology, systematics, physiology, and behavior of marine benthonic invertebrates, fishes, reptiles, and mammals.

Person to be contacted for further information:

The Registrar
Graduate School
U.S. Department of Agriculture
Washington, D. C. 20250

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## FLORIDA INSTITUTE OF TECHNOLOGY

Melbourne, Florida 32901

### DEPARTMENT OF OCEANOGRAPHY

The Department offers a program in physical oceanography. Courses and research in the other fields of marine science and cooperative programs with other institutions emphasize the interrelationships between the various marine sciences. The Department has the use of campus classroom facilities as well as a separate laboratory facility on the ocean. Additional space will be available in a new science building to be built this year.

The undergraduate oceanography curriculum leads to a Bachelor of Science in Physical Oceanography. Emphasis has been placed upon a curriculum that will provide a broad scientific background for the student. The basic requirements provide a sound foundation in physics, mathematics, and electrical engineering, as well as courses involving the application of these basic sciences. The curriculum is designed to meet the needs of industry and government for scientifically trained personnel, which enables the individual to enter into the rapidly developing field of oceanography.

The degree of Master of Science in Oceanography may be conferred upon students who have successfully completed a minimum of 48 quarter hours of required and elective work. Applicants for admission to the program should have a Bachelor's degree in physics, mathematics, physical science, or engineering from an institution acceptable to the Graduate School. All

Physical oceanography graduate students are required to have a mathematical background through differential equations and one year of chemistry.

Instructional Staff:

JACK MORELOCK, Ph.D., Department Chairman and Professor, Oceanography
PIETER S. DUBBELDAM, Ph.D., Associate Professor, Physical Oceanography, and Physics
JAMES A. LASATER, Ph.D., Professor, Chemical Oceanography and Space Technology
WILLIAM M. LAYSON, Ph.D., Adjunct Professor, Physics and Hydroacoustics
LAWRENCE E. MERTENS, Ph.D., Adjunct Professor, Oceanography
ROBERT SCHNEIDER, M.S., Lecturer, Hydroacoustics
JOSEPH SHUMY, B.S., Assistant Instructor, Oceanography
DAVID D. WOODBRIDGE, Ph.D., Director of Research

Degrees Offered:

Bachelor of Science in Physical Oceanography
Master of Science in Physical Oceanography

Courses Offered:

Undergraduate

O 201 INTRODUCTION TO OCEANOGRAPHY
Staff

A study of the relationships and applications of biological, geological, physical, meteorological and engineering sciences to the study of the oceans. A general survey of what the ocean is, where it is, and where it may be going.

O 291 METHODS AND INSTRUMENTS OF OCEANOGRAPHY
Morelock

Theory and use of instruments for oceanographic data collection. Shipboard and laboratory experiments, data evaluation, and instrument design will be covered. Prerequisites: one year of physics, M 251.

O 301 PHYSICAL OCEANOGRAPHY
Staff

Physical properties and distribution of variables in the ocean; chemistry of sea water; theories and methods involved in ocean current study; mass and energy budgets. Prerequisites: Junior standing or approval of the department chairman.

O 302 PHYSICAL OCEANOGRAPHY
Staff

Wave theory, biological and geological properties of the oceans; nature and analysis of ocean waves and currents, wave predictions, tidal theory, wave mechanics and theory.

O 304 GEOLOGY
Morelock

An introduction to physical and historical geology, sedimentation and structural geology for oceanography and engineering students.

O 350 MARINE METEOROLOGY
Woodbridge

Interactions between sea and air, energy budgets and exchange processes, climatology of global exchanges. Prerequisite: M 301.

O 398, 399 FIELD EXPERIENCE IN OCEANOGRAPHY
Staff

Practical oceanographic experience both on board research vessels and in shore laboratories. The activities should include both data acquisition and analysis. Prerequisites: Junior standing and approval of the department chairman.

O 401 OCEAN WAVES AND CURRENTS
Dubbeldam

Application of hydrodynamics, principles to the study of ocean waves and predictions of surface waves. Characteristics and theories of ocean current and the methods of indirect and direct measurement of currents; study of the distribution of mass and properties. Prerequisites: P 402, O 302.

O 402 HYDROACOUSTICS
Layson

Study of acoustical wave theory, transmission and reflection at boundaries, transducer arrays, absorption, and reflection in sea water, sound channels, sound tracking, acoustic telemetering. Prerequisites: O 302, P 330, M 301.

O 490, 491 UNDERGRADUATE THESIS
Staff

Participation in a research program involving the use of research equipment and techniques. This may be part of a group program or an individual project. The results are to be written as an undergraduate thesis presentation. Prerequisites: Senior standing and approval of the department chairman.

Graduate

O 500 INTRODUCTION TO PHYSICAL OCEANOGRAPHY
Layson

The general introduction to physical oceanography, which briefly covers hydrodynamics, heat budgets, chemical and physical properties of sea water, hydroacoustics, instruments and measurements, and geography of the oceans.

O 501 GEOLOGICAL OCEANOGRAPHY
Morelock

A study of the geological structure and sediments of the ocean floors, and the structure and origin of ocean basins. Detailed study of sedimentary processes and the physical properties of marine sediments.

### O 503 CHEMICAL OCEANOGRAPHY

Lasater

A study of the chemical and physical properties of sea water. Detailed study of salinity, dissolved gases, densities, geochemical considerations, mass action principles, principal constituents of sea water, corrosion.

### O 504 CHEMICAL OCEANOGRAPHY II

Lasater

Selected topics in chemical oceanography including: minor constituents of sea water, organic constituents of sea water, organic productivity of the ocean, bacterial corrosion, anoxic basins. Prerequisite: O 503.

### O 506 SEA LABORATORY TECHNIQUES

Staff

Practice in the collection and analysis of standard oceanographic data. Part of this course will be conducted at sea. Prerequisites: O 500, O 503.

### O 507 LABORATORY TECHNIQUES IN OCEANOGRAPHY

Staff

Analytical methods used in chemical, geological and physical oceanography. Prerequisites: O 500, O 501, O 503 or approval of the department chairman.

### O 510 SEMINAR

Morelock

Presented by the students. Topics for lectures are drawn from student research or literature review.

### O 511 OCEAN WAVES

Dubbeldam

Theoretical approach to the hydrodynamics of wave motion for both surface and internal waves. Investigation of wave spectra and analysis, refraction, wind waves, and swell and surf, wave prediction. Prerequisite: M 586.

### O 512 TIDES AND TIDAL CURRENTS

Staff

Theories of the astronomical tides; geographical variations; analysis and predictions; tide producing forces.

### O 513 DYNAMIC OCEANOGRAPHY

Dubbeldam

The geophysical structure of the sea; gravity, field of mass and pressure field and their relationship to the structure of the sea. Representation of ocean movement and general theory of ocean currents in a homogeneous sea, determination of reference levels and transport functions. Prerequisite: M 586.

### O 514 DYNAMIC OCEANOGRAPHY II

Dubbeldam

A theoretical study of current conditions at boundary surfaces, currents in a non-homogeneous ocean, effects of wind on mass, field and density currents, basic principles of ocean circulation, wind driven and thermohaline circulation, Ekman wind drift, Sverdrup's internal solution, Stommel's westward intensification.

### O 515 ENGINEERING ASPECTS OF OCEANOGRAPHY

Morelock

The application of ocean wave theory to engineering problems: includes long wave theory, wave spectra, wave generation and prediction, modification of wave form. Prerequisites: M 586, P 515.

### O 516 MARINE METEOROLOGY

Woodbridge

Interactions between sea and air, energy budget, unified linear pertubation theory of rotating stratified fluid with application to ocean and atmosphere, methods of analysis of motions.

### O 517 MARINE THERMODYNAMICS

Lasater

Thermodynamics of the interactions of air masses and sea water. Thermal properties and behavior of sea water. Interpretations of the interactions and mixing of water masses. Prerequisites: P 404, O 504, O 516.

### O 520 HYDROACOUSTICS

Layson

The theoretical study of the fundamental relations, general theory and shallow water transmission of energy in the ocean. Detail coverage of components of stress, strain and motion, waves of finite amplitude, ray characteristics, refraction of dispersive wave train, boundary conditions, ray solutions, an surface image interface. Prerequisite: P 515.

### O 521 HYDROACOUSTICS II

Layson

Transmission in deep water, reflectivity and attentuation. Ray and normal-mode solutions for deepwater transmission; effects of negative and positive velocity gradients on transmission; effects of absorption, scattering, and diffraction.

### O 530 OCEANOGRAPHIC INSTRUMENTS

Morelock

Installation and use of equipment for oceanographic instrumentation. Hydrophones, transducers, transponders, Nansen bottle, bathythermograph, velocimeter, current meters, depth recorders, and other instruments will be used.

**O 599 SPECIAL TOPICS IN PHYSICAL OCEANOGRAPHY**
Staff

Special topics to suit individual on small group requirements. This course is designed to cover problems not included in thesis research or another course in the established curriculum.

**O 605, 606 THESIS**
Staff

Individual work under the direction of a member of the graduate faculty on a selected topic in the field of oceanography.

Person to be contacted for further information:

Dr. Jack Morelock
Department of Oceanography
Florida Institute of Technology
Melbourne, Florida 32901

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## FLORIDA PRESBYTERIAN COLLEGE
St. Petersburg, Florida 33733

The College does not offer graduate work nor does it provide for a baccalaureate degree in marine science as such. Being situated on the waterfront of Boca Ciega Bay much emphasis in several undergraduate courses is placed on marine sciences, however, and students are encouraged to pursue programs and research independently.

Instructional Staff:

JOHN C. FERGUSON, Ph.D., Associate Professor of Biology, echinoderm physiology; morphology of marine invertebrates
GEORGE K. REID, Ph.D., Professor of Biology, ecology of estuaries and littoral zones
RICHARD W. NEITHAMER, Ph.D., Professor of Chemistry, chemistry of sea water
RICHARD A. RHODES II, Ph.D., Assistant Professor of Physics, underwater acoustics

Courses Offered:

**Biology 312 ECOLOGY**
Reid

Physical, chemical, and biological interrelationships in natural communities. Emphasis is marine environments.

**Biology 321 INVERTEBRATE ZOOLOGY**
Ferguson

A study of the structure, function, and interrelations of invertebrate animals. Much field collecting and study of the animals in their natural environments is conducted in the bay.

**Winter Term**
Ferguson, Reid, Neithamer, Rhodes

The month of January is devoted to independent study and research. Students may choose problems in marine ecology biology of marine animals, chemistry of sea water, tidal and current dynamics, underwater acoustics, and related topics.

Person to be contacted for further information:

I. G. Foster, Chairman
Division of Mathematics and
the Natural Sciences
Florida Presbyterian College
St. Petersburg, Florida 33733

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## FLORIDA STATE UNIVERSITY
Tallahassee, Florida 32306

### DEPARTMENT OF OCEANOGRAPHY

The Department, a part of the Science Center at the main campus, offers a graduate program leading to the M.S. and Ph.D. degrees in all phases of oceanography. It presently occupies approximately 20,000 square feet of space in temporary buildings. A wide range of equipment, including a CDC 3400 Computer Center, is available within the Department and science center for all phases of oceanographic research and teaching.

A shore facility at Turkey Point on the Gulf of Mexico, 46 miles from the campus, will be completed in 1967. The facility, with a 180'x 200' boat basin will accommodate vessels of a draft of less than 12 feet. The facility will provide all of the usual services and have a 180' dock, air conditioned large shop, laboratory of 8,500 square feet with running sea water, and dormatory space. An air-conditioned 65' vessel with collecting equipment, a 30' cabin cruiser and several small boats are available for inshore work. Within the Department of Geology is the National Science Foundation Antarctic Marine Geological Research Facility for storing and processing Antarctic sediments.

Instructional Staff:

CARL H. OPPENHEIMER, Ph.D., Professor, Chairman, Biological Oceanography
HENRY KRITZLER, Ph.D., Professor and Resident Science Director of Turkey Point Facilities, Marine Ecology
H. GRANT GOODELL, Ph.D., Associate Professor, Director of Antarctic Marine Geology Research Facility; Marine Geology and Geochemistry
R. WINSTON MENZEL, Ph.D., Associate Professor, Fisheries Biology and Marine Biology
RAYMOND C. STALEY, Ph.D., Associate Professor, Physical Oceanography
MICHAEL GARSTANG, Ph.D., Assistant Professor, Physical Oceanography

DETLEF A. WARNKE, Ph.D., Assistant Professor, Geological Oceanography
JAMES JONES, Ph.D., Geological Oceanography
WALTER A. GLOOSCHENKO, Ph.D., Assistant Professor, Biological Oceanography
WILHELM SCHWARTZ, Ph.D., Visiting Professor, Marine Microbiology
KENNETH L. WARSH, Ph.D., Assistant Professor, Physical Oceanography
YA HSUEH, Ph.D., Assistant Professor, Physical Oceanography
ROBLEY LIGHT, Ph.D., Assistant Professor, Chemical Oceanography
MICHAEL J. GREENBERG, Ph.D., Associate Professor, Biological Oceanography

Degrees Offered:

The Department of Oceanography offers an interdisciplinary program leading to the Master of Science and Doctor of Philosophy degrees in the fields of biological, chemical, geological, and physical oceanography.

Courses Offered:*

Courses for graduate students and advanced undergraduate students

401 ELEMENTARY PHYSICAL OCEANOGRAPHY

Physical properties of sea water; heat budget of the oceans; processes, theories and methods involved in ocean currents, tides and waves. May not be counted for graduate credit by physical oceanography majors. Prerequisites: Physics 103 or 203, Mathematics 130; Chemistry 103 or equivalents.

402 INTRODUCTION TO PHYSICAL OCEANOGRAPHY

Physical properties, processes, and the theory of variables in the sea; mass and energy budgets; methods of measurement and computation of ocean currents; nature and analysis of surface waves, tides and tidal currents. Prerequisites: Physics 204 or 204H, Mathematics 252; Chemistry 103.

403 EXPERIMENTAL OCEANOGRAPHY

Lectures and field work on shipboard and ashore in all areas of oceanography. Design of experiments, collection of data, analysis of data and preparation of scientific results. Prerequisites: Minimum of two courses from Oceanography 401, 426, 450, and 461, or their equivalents.

421 OCEANIC ZOOGEOGRAPHY

General biota and life zones in the oceans. Influence of chemistry, geology, and physical factors on the distribution and life histories of marine invertebrates and vertebrates. Prerequisites: Permission of the instructor.

422 GEOMICROBIOLOGY

Role of microbes in geological and geochemical processes. Prerequisites: Permission of instructor.

426 ELEMENTARY BIOLOGICAL OCEANOGRAPHY

Survey of animal and plant kingdom, productivity concepts, basic principles of marine biogeography and marine biological phenomena of general interest. Same as Biology 426.

427 ESTUARINE POLLUTION

Laboratory experiments, lectures and survey of characteristics, analysis and treatment of estuarine pollutants. Prerequisites: Organic Chemistry, General Bacteriology.

430 GENERAL MARINE BIOLOGY

An examination of the biota of the world's oceans. Historical developments of marine environments and biota, application of ecological concepts, energy flow, biogeography and human utilization of marine resources. Same as Biology 430. Prerequisites: Biology 409.

431 MARINE ECOLOGY

Offered at the Marine Station only. Same as Biology 431. Prerequisites: Biology 203.

441 GEOPHYSICAL MEASUREMENTS I

Theory and practice of calibration and operation of basic sensors and measuring devices in geophysics. Instruments to measure temperature, heat flow, fluid flow, pressure and moisture are used as examples. Same as Meteorology 441. Prerequisites: Physics 205 or equivalent.

450 ELEMENTARY CHEMICAL OCEANOGRAPHY

The chemical composition of sea water, carbon dioxide system, nutrients, laboratory methods for sea water chemistry. May not be counted for credit by chemical oceanography majors. Prerequisites: 1st year General Chemistry.

458 PHYSICS OF THE AIR-SEA BOUNDARY LAYER

Fundamentals of the flux of momentum, heat and water; study of air-sea interaction mechanisms of exchange and budgets. Same as Meteorology 458. Prerequisites: Oceanography 402 or concurrent enrollment in Meteorology 425.

464 MARINE MICROBIOLOGY

The role of microorganisms in the economy and productivity of the sea. Same as Biology 464. Prerequisites: Biology 361 or equivalent.

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* Instructors for all classes are to be announced.

### 471 GEOCHEMICAL INSTRUMENTATION

Theory and practical experiments in the use of advanced equipment for geochemical analysis and field work. Prerequisites: Permission of instructor.

### 481 ELEMENTARY GEOLOGICAL OCEANOGRAPHY

Principles and problems of marine geology. Same as Geology 481. Prerequisite: Geology 206 or equivalent.

### 502 DYNAMIC OCEANOGRAPHY

Lagrangian and Eulerian viewpoints in oceanography; the Navier-Stokes equations; Reynolds averaging, turbulent motion, diffusion processes in the ocean; large scale flow in oceans. Prerequisites: Meteorology 323.

### 503 CLASSICAL HYDRODYNAMICS

Classical hydrodynamics of viscous and non-viscous fluids in an inertial coordinate system. Same as Meteorology 523. Prerequisites: Vector algebra and Vector calculus.

### 504 MARINE HYDRODYNAMICS

A study of techniques for solving problems in physical and dynamical oceanography. Applications of dimensional analysis and similarity solutions; diffusion and mixing of sea water, boundary value problems including currents and tides in closed basins. Prerequisites: Oceanography 402, Meteorology 323.

### 505 OCEAN WAVES

Marine hydrodynamics applied to wave motion in oceans, including internal and surface waves; theory and forecasting of wind-generated surface waves. Prerequisites: Oceanography 504, 523, or consent of instructor.

### 506 OCEAN CIRCULATION

Hydrodynamic theories concerning origin and characteristics of ocean currents. Prerequisites: Oceanography 504, 523, or consent of instructor.

### 522 ECOLOGY AND TAXONOMY OF BENTHIC COMMUNITIES

Population dynamics of communities in different benthic zones in the ocean. Prerequisite: Invertebrate Zoology.

### 523 ZOOPLANKTON ECOLOGY

Distribution and life histories of zooplankton as a function of oceanographic features. Prerequisites: Invertebrate Zoology.

### 524 ADVANCED MARINE ALGOLOGY

The study of life histories and ecology of benthic algae and phytoplankton in marine environments. Prerequisites: Biology 463 or equivalent.

### 526 LITTORAL SANITARY ENGINEERING

The comparison of natural and polluted environments with emphasis on microbial and biochemical factors. Prerequisites: Biology 462, 464, 465, 466 or equivalent; Chemistry Quantitative Analysis and Biochemistry.

### 527 FISHERY BIOLOGY

Principles and techniques employed in the management of commercial and game fisheries, with special reference to the freshwater and marine species of Florida. Same as Biology 571. Prerequisite: Permission of instructor.

### 541 MARINE CHEMISTRY

The chemical equilibrium of sea water and space-time distribution of elements. Prerequisites: Chemistry major or permission of instructor.

### 558 LABORATORY IN AIR-SEA INTERACTION

Laboratory and field experiments in study of transfer problems in liquids and gases. Direct measurement of stress; determination of profiles of wind, temperature and water vapor over the ocean; influence of ocean boundary layer. Same as Meteorology 558. Prerequisites: Oceanography 458 and 441.

### 581 BATHYMETRY, STRUCTURE, AND TECTONICS OF OCEAN BASINS

A review of the crustal configuration of the oceans as established by magnetic, gravity, heat flow, and seismic data and a comparison with continental areas. Same as Geology 581. Prerequisites: Undergraduate degree in Geology or equivalent.

### 582 OCEANIC PROCESSES OF SEDIMENTATION

Quantitative approach to the hydrodynamics of the sediment-water system together with a survey of marine processes of sedimentation. Same as Geology 582. Prerequisites: Undergraduate degree in Geology or equivalent.

### 583 OCEAN SEDIMENTS

The nature, distribution, and genesis of marine sediments; littoral to abyssal. Same as Geology 583. Prerequisites: Undergraduate degree in Geology or equivalent, plus Oceanography 561 and 562.

### 591ABC DIRECTED INDIVIDUAL STUDY

These courses are offered to meet the requests for individual work by students. All M.S. candidates in residence are expected to participate.

### 595AB SEMINAR

Meets weekly for reports and discussion of recent research within and without the Department.

597ABC DIRECTED TEACHING

Candidates for the Master's degree may, at the appropriate level, register for credit in Directed Teaching. Under the supervision of staff members, the student will participate in the teaching of specified lectures and laboratories in all fields of oceanography. The student will be responsible for those particular aspects of a lecture or laboratory course which will enhance his training and knowledge.

598ABC DIRECTED RESEARCH

The purpose of Directed Research is to expose the student to specific research problems in oceanography which are being carried out by members of the staff. This research will be distinct from the student's thesis problem, but methodology, experimental techniques, analysis and compilation of results will all bear upon the general problem of research work.

599 THESIS

Individual research in oceanography to be planned with the major professor.

695AB SEMINAR

Meets weekly for reports and discussions of recent oceanographic research within or without the Department. All Ph.D. students in residence are expected to participate.

699 DOCTORAL DISSERTATION

Individual research to be planned with the major professor.

Person to be contacted for further information:

Dr. Carl H. Oppenheimer
Chairman
Department of Oceanography
Florida State University
Tallahassee, Florida 32306

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## NOVA UNIVERSITY
Fort Lauderdale, Florida 33316

### PHYSICAL OCEANOGRAPHIC LABORATORY

The Laboratory which is part of the Physical Science Center of the University, offers instruction and research leading to the Ph.D. in Physical Oceanography. The program offered is not a broad oceanographic curriculum covering all phases of oceanography, but rather an intensive study of the physics of the sea. Emphasis is on modern theories of the circulation of the oceans and experimental work at sea to study these problems.

The Laboratory is housed on a floating structure providing 3,600 square feet and small additional structures ashore. A second floating laboratory for studies in marine biology is now being completed and research in this field will begin in the fall of 1967. A high speed (20 kts.) steel vessel, R/V GULFSTREAM is available for work at sea. The Laboratory has unique instrumentation capabilities and an in-house computer. Supporting engineering and technical staff are available.

Instructional Staff:

WILLIAM S. RICHARDSON, Ph.D., Professor of Oceanography
PEARN P. NIILER, Ph.D., Assistant Professor of Theoretical Oceanography
WILLIAM J. SCHMITZ, JR., Ph.D., Post Doctoral Fellow in Oceanography
CHARLES S. YENTSCH, M.S., Associate Professor of Marine Biology

Degrees Offered:

Doctor of Philosophy in Physical Oceanography

Courses Offered:

Undergraduate

None

Graduate

Students will be accepted for candidacy for the degree of Doctor of Philosophy in Physical Oceanography or in Physics with an oceanography major. These two options do not define different programs of study but rather a minor change of emphasis. In general, two full academic years are required in preparation for dissertation research. The dissertation itself will involve original research leading to new knowledge about the ocean. The course of study will encompass the following general topics. NOTE: Courses are not numbered.

A. Physical Oceanography - 2 years

1. Scientific method with emphasis on its application to the environmental sciences.

2. A description of the earth, the atmosphere and the oceans.

3. The energy balance of the earth, the atmosphere and the oceans, air-sea interaction.

4. The physical and chemical properties of sea water.

5. The distribution of conservative and non-conservative properties.

6. The circulation of the oceans.

7. Tides and tidal currents.

8. Waves.

B. Fluid Mechanics and Applied
Mathematics - 2 years

These two areas will be developed as an integral unit, the mathematical methods being introduced as they are essential to the subject matter.

1. Introduction to continuum mechanics.

2. The experimental and historical development of the ideas of a fluid continuum.

3. Hydrodynamics and Navier-Stokes fluids.

4. Modeling, scaling and similarity laws.

5. Classical problems in incompressible flow.

6. Geophysical fluid dynamics of the atmosphere and oceans.

C. Physics, Chemistry, Biology, Mathematics or Advanced Engineering - 1 year

It is expected that this one year of work in a scientific elective will be carried out under faculty outside of the Physical Oceanographic Laboratory.

D. General Elective - 1 year

It is suggested that the one year elective course be used to strengthen the background of the student in his particular interest and prepare him more fully for a particular thesis problem. The student is left free, however, to become involved in any course of study at the University.

E. Selected Reading and the Development of Experimental Competence - 1 year

The student's progress in his studies will be tested periodically in a series of cumulative examinations. At least one year of residence is required.

Person to be contacted for further information:

William S. Richardson
Physical Oceanographic Laboratory
Nova University
1901 S.E. 15th Street
Fort Lauderdale, Florida 33316

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## UNIVERSITY OF FLORIDA
Gainesville, Florida 32601

The University of Florida Marine Laboratory on Seahorse Key, an island about two miles from Cedar Key, consists of a laboratory with fresh and sea water and a 10 room building used as a dormitory and caretaker's quarters.

Instructional Staff:

HARVEY K. BROOKS, Ph.D.
JOHN W. BROOKBANK, Ph.D.
ROBERT DeWITT, Ph.D.
CARTER R. GILBERT, Ph.D.
FRANK J. S. MATURO, Ph.D.
FRANK G. NORDLIE, Ph.D.
E. LOWE PIERCE, Ph.D.

Degrees Offered:

M.S. and Ph.D.
No specific degrees are offered in
Marine Science

Courses Offered:

Undergraduate

| | | |
|---|---|---|
| Zoology 308 | INVERTEBRATE ZOOLOGY | Maturo |
| Zoology 309 | COMPARATIVE ANATOMY | Nordlie |
| Zoology 310 | EMBRYOLOGY | Brookbank |
| Geology 517 | MARINE GEOLOGY | Brooks |

Graduate

| | | |
|---|---|---|
| Zoology 641 | COMPARATIVE PHYSIOLOGY | DeWitt |
| Zoology 651 | ICHTHYOLOGY | Gilbert |
| Zoology 612 | MARINE BIOLOGY | Pierce |

Person to be contacted for further information:

Dr. E. Lowe Pierce
Department of Zoology
College of Arts and Sciences
University of Florida
Gainesville, Florida 32601

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## UNIVERSITY OF SOUTH FLORIDA
Tampa, Florida 33620

The Department of Marine Science located at the Bay Campus in St. Petersburg has adequate office and laboratory space available in permanent buildings. Additional facilities consist of more than 2,000 feet of docking space with a mean depth of 19 feet, an 85 foot shrimp boat owned by the State Board of Conservation, and a number of smaller craft.

The facility is used during the academic year for marine science and during the summer for both teaching and research. Housing for students and visiting scientists can accommodate 48 persons.

Instructional Staff:

HAROLD J. HUMM, Ph.D., Professor, Director, Marine Biology
DEAN F. MARTIN, Ph.D., Associate Professor, Marine Chemistry
THOMAS L. HOPKINS, Ph.D., Assistant Professor, Marine Biology
HUGH H. DeWITT, Ph.D., Assistant Professor, Marine Biology

Degrees Offered:

M.S. in Marine Science proposed for Fall of 1968.

Courses Offered:*

### OGY 311 INTRODUCTION TO OCEANOGRAPHY

A survey of modern oceanography and its methods, including the important features of physical, chemical, biological and geological oceanography.

### OGY 521 CHEMICAL OCEANOGRAPHY

Martin

The ocean as a chemical system, including composition, physical-chemical aspects, trace metals, and methods of analysis. Lec-Lab. Prerequisite: CH 212 or equivalent course in introductory chemistry.

## Zoology

### ZOO 313 INVERTEBRATE ZOOLOGY

Friedl

An introduction to the major invertebrate groups, with emphasis on local marine forms. Lec-Lab. Prerequisite: ZOO 202 or equivalent introductory zoology course.

### ZOO 515 PLANKTOLOGY

Hopkins

Identification, life history and population dynamics of important planktonic species. Prerequisite: ZOO 313 or equivalent course in invertebrate zoology.

### ZOO 519 ICHTHYOLOGY

DeWitt

Systematics of fishes, including major classification, comparative anatomy, embryology, and general distribution. Lec-Lab. Prerequisite: ZOO 311 or equivalent course in comparative vertebrate anatomy.

### ZOO 523 PHYSIOLOGY OF MARINE ANIMALS

Lawrence

A study of the physiological mechanisms of animals in the marine environment. Lec-Lab. Prerequisite: ZOO 421 or equivalent course in general physiology.

### ZOO 533 PHYSIOLOGY OF FISHES

Liston

The physiological function and adaptations of fishes. Lec-Lab. Prerequisite: ZOO 521 or equivalent course in comparative animal physiology.

## Botany

### BOT 443 MARINE BOTANY

Dawes

An introduction to the ecology, physiology, morphology, and taxonomy of marine plant life. Lec-Lab. Prerequisite: BOT 202 or equivalent course in introductory botany.

### BOT 543 PHYCOLOGY

Humm

A detailed survey of the algae emphasizing both taxonomy and morphology of fresh and marine water forms. Lec-Lab. Prerequisite: BOT 443 or equivalent course in marine botany.

## Geology

### GLY 411 MARINE GEOLOGY

Fundamentals of marine geology involving collection, analysis and interpretation of marine specimens. Prerequisite: GLY 402.

Person to be contacted for further information:

Harold J. Humm
Director
Department of Marine Sciences
University of South Florida
St. Petersburg, Florida 33733

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## UNIVERSITY OF WEST FLORIDA
Pensacola, Florida 32504

The University of West Florida is a new upper-division (junior, senior, graduate) institution which will open its doors to undergraduates September, 1967. This state university is designed to take students who have completed two years of undergraduate work. Because of its proximity to the marine environment, the University will be marine oriented in many aspects. Its biology faculty, in particular, will emphasize marine biology; to a lesser extent, the faculties of chemistry, physics, and math will also be involved in oceanographic studies. A masters program in marine biology is anticipated by September, 1969.

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* Courses numbered 500 or above are available for graduate credit.

The 1,000 acre campus, situated on the Escambia River at the head of Escambia Bay, will originally house all of the marine biological studies. Living marine organisms will be available and maintained on the main campus when we open in September, 1967. Construction of a separate marine laboratory is anticipated on our island campus which has waterfront property on both the Gulf of Mexico and Pensacola Bay. The 125 acre island campus is some 20 miles from the main campus via high speed roads.

Instructional Staff:

ALFRED B. CHAET, Ph.D., Provost, Gamma College and Professor of Biology
ROGER REID, Ph.D., Professor of Biology
THOMAS HOPKINS, Ph.D., Associate Professor of Biology

Others to be announced in the immediate future.

Degrees Offered:

Bachelor of Science in Biology
Master of Science in Marine Biology anticipated by 1969

Courses Offered:

DEVELOPMENTAL BIOLOGY

Development from a molecular, cellular and multicellular aspect. Problems of induction, regulation, differentiation, etc.

ORGANISM BIOLOGY

Structure and function of higher organisms including such topics as biological rhythms, electrophysiology, neurosecretion, etc.

ECOLOGICAL ADAPTATIONS

The dynamics of marine organismic interaction. Environmental and internal reactions, symbiosis and competition, homeostasis, natural selection of marine organisms, limited marine field trips.

INDEPENDENT STUDY IN MARINE TOPICS

SEMINARS IN MARINE PROBLEMS

Person to be contacted for further information:

Dr. Alfred B. Chaet
Provost, Gamma College and
Professor of Biology
University of West Florida
Pensacola, Florida 32504

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## UNIVERSITY OF MIAMI
Miami, Florida 33149

### INSTITUTE OF MARINE SCIENCES

The Institute encompasses both the Marine Laboratory, which conducts research in marine science, and the Department of Marine Science which provides academic instruction. The Laboratory employs a 176-foot converted cargo vessel, a 75-foot research vessel, and several small motor vessels. Other facilities include extensive laboratory space, the Marine Biological Museum, a large library, a salt-water circulation building for experimental ecology and behavior studies of fishes and invertebrates, and a physical sciences wing, etc.

Training is offered primarily to graduate students although a few strictly undergraduate courses are taught. For academic purposes the Institute is divided into four research divisions (Fishery Sciences, Physical Sciences, Biological Sciences, and Oceanographic Engineering). Students who show research ability and meet the necessary requirements may take part in investigations being carried on as part of the Marine Laboratory's program.

Instructional Staff:

F. G. WALTON SMITH, Director and Professor of Oceanography
FREDERICK M. BAYER, Ph.D., Professor of Marine Biology, Invertebrates
ENRICO BONATTI, Ph.D., Assistant Professor of Marine Physical Science, Geology
SAUL BROIDA, Ph.D., Assistant Professor of Marine Physical Science, Physics
T. S. CHEUNG, Ph.D., Assistant Professor of Marine Biology, Physiology
EUGENE F. CORCORAN, Ph.D., Associate Professor of Marine Physical Science, Chemistry
DONALD P. de SYLVA, Ph.D., Associate Professor, Marine Biology, Ichthyology
WALTER DROST-HANSEN, Ph.D., Professor, Marine Physical Science, Physics
CESARE EMILIANI, Ph.D., Professor, Marine Physical Science, Geology
HOMER HISER, Ph.D., Professor, Marine Physical Science, Atmospheric Science
DAVID A. HUGHES, Ph.D., Assistant Professor, Fisheries Science, Behavior
CLARENCE P. IDYLL, Ph.D., Professor of Fisheries Science
EDWIN S. IVERSEN, Ph.D., Associate Professor of Fisheries Science, Parasitology.
MORTON KRONENGOLD, B.S., Assistant Professor of Marine Physical Science, Physics
CHARLES E. LANE, Ph.D., Professor, Marine Biology, Physiology
SAMUEL P. MEYERS, Ph.D., Associate Professor, Marine Biology, Biology
HILARY B. MOORE, Ph.D., Assistant Professor, Marine Biology, Ecology

ARTHUR A. MYRBERG, Ph.D., Assistant Professor, Marine Biology, Behavior
HANS GOTE OSTLUND, Ph.D., Associate Professor, Physical Science, Geology
HARDING OWRE, Ph.D., Assistant Professor, Marine Biology, Plankton (Embryology)
JOSEPH PROSPERO, Ph.D., Assistant Professor, Marine Physical Science, Physics
ANTHONY J. PROVENZANO, Ph.D., Associate Professor, Marine Biological Science, Invertebrates
MARTIN A. ROESSLER, Ph.D., Instructor of Fisheries Science
RUSSELL L. SNYDER, Ph.D., Assistant Professor, Marine Physical Science, Physics
JOHN C. STEINBERG, Ph.D., Professor, Marine Physical Science, Acoustics
ROBERT A. STEVENSON, Ph.D., Assistant Professor, Marine Biology, Behavior
LOWELL P. THOMAS, Ph.D., Assistant Professor, Marine Biology, Invertebrates
GILBERT L. VOSS, Ph.D., Professor, Marine Biological Science
ROBERT B. WILLIAMS, Ph.D., Professor of Natural Science
E. J. FERGUSON WOOD, Ph.D., Professor of Marine Biological Science, Botany

Degrees Offered:

M.S. and Ph.D. in Marine Science

Courses Offered:

Fisheries Science

Senior and Graduate Courses

0501. FISHERY BIOLOGY

Commercial fishing methods; statistics of catch and effort; sampling of fish and invertebrate populations; food and feeding; age and growth; spawning. Lecture, 3 hours; laboratory, 4 hours. Field trips as required. Prerequisite: Permission of instructor.

0502. FISHERY TECHNOLOGY

Preservation of fish; tests of quality; processing and transportation of fishery products. Lecture, 1 hour; laboratory, 3 hours. Prerequisite: 501 or permission of instructor.

0521. SALTWATER POLLUTION TECHNOLOGY

Methods of biological, chemical, and physical analysis of saltwater bays and estuaries for industrial and other pollution. The principal types of pollution and their effects upon marine life, with emphasis on the shellfish and scale fish populations. Preventive and corrective measures. Lecture, 2 hours; laboratory and field trips as required. Prerequisite: Quantitative Analysis and General Bacteriology or Sanitary Engineering. By appointment.

Graduate Courses

602. FISHERY SEMINAR

Required of all majors in fisheries.

604. FISH STOCKS AND THEIR MANAGEMENT

Theory of maximum sustained yield; migrations; fluctuations in abundance; effects of fishing and other factors on stocks; biological and economic theories of management; international conflicts. Lecture, 3 hours; laboratory, 4 hours. Field trips as required. Prerequisite: 501 for majors; permission of instructor for non-majors.

605. POPULATION ENUMERATION AND DYNAMICS

Advanced theory and methods of estimating the sizes of populations of invertebrates and fishes; effect of fishing on the abundance and yield from animal stocks. Lecture, 2 hours; laboratory, 3 hours. Prerequisite: 604.

606. BIOLOGY OF MARINE PARASITES

Theoretical and practical problems of parasites of marine animals, chiefly of commercial and recreational value. Host-parasite relationships are related to dynamics of marine populations and the use of parasites as ecological labels. Lecture, 3 hours; laboratory, 4 hours. Prerequisite: Biology 314, or permission of instructor.

671-673. ADVANCED STUDY IN FISHERIES

Supervised study in areas of special interest to graduate students. Prerequisite: Permission of department.

681, 682. FISHERY RESEARCH

Advanced research allowed for credit only beyond the 30 credits required for the degree. Not applicable to thesis work at the University of Miami. Registration by permission of department.

Research 600, 700 toward master's thesis or doctoral dissertation, see the Bulletin of the Graduate School.

Marine Biological Science

Undergraduate Courses

208. INTRODUCTION TO BIOLOGICAL OCEANOGRAPHY

Introduction to the biology of the common marine animals and plants of the shore, coral reefs, and open ocean. Economic applications, and relations to other marine sciences. Laboratory study and field observations of tropical marine organisms, shore collecting and dredging. Lecture, 2 hours; laboratory, 4 hours; collecting trips, 6 hours. Prerequisite: Biology 101 or permission of instructor.

## enior and Graduate Courses

### 04. GENERAL BIOLOGICAL OCEANOGRAPHY

Survey of marine animals and plants and interrelationships including primary production, predation, and symbiosis. Physiological processes of marine organisms and alteration by temperature, salinity, light, density and oxygen; oceanographic factors, such as water masses, upwelling, and thermocline; and vertical and horizontal zonation in the oceans. Current research literature. Lecture, 2 hours; field trips. Prerequisite: 16 credits in Biology or permission of the instructor.

### 05. GENERAL BIOLOGICAL OCEANOGRAPHY LABORATORY

Anatomy, classification, and identification of Florida littoral, sub-littoral, and oceanic marine fauna and flora. 6 hours. Corequisite with 504.

### 12. PHYCOLOGY

The morphology, taxonomy, physiology, and ecology of marine algae including phytoplankton. Lecture and conference, 2 hours; laboratory, 4 hours; field trips. Prerequisite: 204 and Biology 207. By announcement.

### 31. MARINE MICROBIOLOGY

Taxonomy, physiology and ecology of marine microorganisms. Biochemical considerations and economic significance. Lecture, 2 hours; laboratory, 4 hours. Prerequisite: Biology 102 and 308. By announcement.

### 41. MARINE BIOCHEMISTRY

Biochemistry of organisms, water and sediment in the marine environment. Lecture, 3 hours; demonstrations. Prerequisite: Chemistry 202, 216 and 310 or permission of instructor. By announcement.

## raduate Courses

### 02. BIOLOGICAL OCEANOGRAPHY SEMINAR

Required of all majors in Marine Biological Science.

### 21. TAXONOMY OF MARINE INVERTEBRATES

The classification, anatomy, and life histories of marine invertebrates. Detailed studies of a selected group from material collected in the Florida area. Lecture, 2 hours; laboratory, 4 hours; field trips. Prerequisite: Biology 200 (Invertebrate Zoology) and permission of instructor.

### 622. ECOLOGY OF MARINE ANIMALS

Types of environment in the ocean, with special reference to shallow tropical seas; the relation of distributions to the physical and chemical environment; effects of environmental changes; breeding cycles; plankton and food chains; causes of population fluctuations. Application of ecological techniques to local problems. Lectures, conferences, and field trips, 8 hours. Prerequisite: Permission of instructor.

### 623. INVERTEBRATE EMBRYOLOGY

Early development of invertebrates including the protochordates; life histories, larval stages, and metamorphoses of the principal types and their evolutionary significance; larval adaptation, methods, and techniques. Lecture, 2 hours; laboratory, 6 hours. Prerequisite: Biology 200 (Invertebrate Zoology) and Biology 301 (Vertebrate Embryology).

### 625. BEHAVIOR OF MARINE ORGANISMS

Sensory physiology; acuity and sensitivity of marine organisms and their sensory adaptation to various marine environments. Sound production and its significance in communication; social behavior; predator-prey relationships. Prerequisite: Marine Biological Science 504, Physiology, or permission of instructor.

### 631. PLANKTON

The drifting organisms, the influence of environment factors upon them, their place in the economy of the sea and freshwater habitats, and their relation to fisheries. Lecture, 2 hours; laboratory or field, 4 hours. Prerequisite: Biology 200 (Invertebrate Zoology), or permission of instructor.

### 632. PHYTOPLANKTON

Introduction to taxonomy; nutrition and ecology of planktonic, epontic, and benthic microorganisms; plant productivity, growth and grazing; effect of physical and chemical factors; relations of organisms to environment; marine ecosystems. Prerequisite: Permission of instructor.

### 634. PHYSIOLOGY OF MARINE ORGANISMS

Osmotic regulation, behavior, feeding, metabolism, nerve and muscle function, endocrines, blood chemistry, excretion. Lecture, 2 hours; laboratory, 4 hours; field work as required. Prerequisite: Biology 311 (General Physiology).

### 671-679. ADVANCED STUDY IN MARINE BIOLOGICAL SCIENCE

Supervised study in areas of special interest to graduate students. Prerequisite: Permission of department.

### 681, 682. MARINE BIOLOGICAL RESEARCH

Advanced research allowed for credit only beyond the 30 credits required for the degree. Not applicable to thesis work at the University of Miami. Registration by permission of department.

### 686. BIOLOGY OF FISHES

Emphasis on marine fishes and their ecology. Review of various anatomical systems as related to environment and mode of life. Growth, reproduction, respiration, sense systems, adaptation of larvae. Lecture 2 hours; laboratory (or demonstrations) 3 hours. Field trips as time and weather permit. Prerequisite: 687 or equivalent and permission of instructor.

### 687. SYSTEMATICS OF FISHES

History of ichthyology. Classification and evolution of major groups of fishes with emphasis on the family level and higher. Current research and literature on modern groups. Speciation, zoogeography, methods. Lecture, 3 hours; laboratory, 3 hours. Field trips as time and weather permit. Prerequisite: 504, Biology 201 or 202 or equivalent; permission of instructor.

Research 600, 700 toward master's thesis or doctoral dissertation, see the Bulletin of the Graduate School.

## Marine Physical Science

## Undergraduate Courses

### 203. INTRODUCTION TO OCEANOGRAPHY

An introduction to the physical nature of the ocean, its topography and circulation. Chemical nature of ocean water. Bottom deposits. Relation to biological, geographical, geological and economic problems, including fisheries. Lecture, 2 hours; laboratory, 3 hours; field work by arrangement.

## Graduate and Senior Courses

### 501. GENERAL OCEANOGRAPHY

Physical properties and chemical composition of sea water, and relationships to activities of plants and animals; main features of the physics of the oceans; quantitative chemical and physical methods; use of oceanographic instruments. Lecture, 3 hours. Prerequisite: Physics 212 and Chemistry 110 or 111 and 112 or permission of the instructor.

### 520. CHEMICAL OCEANOGRAPHY

Ocean Chemistry; relation to hydrodynamical, physical, meteorological, geological, and biological problems. Special methods in quantitative determination of inorganic and organic constituents. Lecture 2 hours; laboratory, 6 hours, field work as required. Prerequisite: 0501 and Chemistry 216 (Quantitative Analysis).

### 522. PHYSICAL CHEMISTRY IN THE EARTH SCIENCES

Thermodynamic and kinetic aspects of chemical oceanography and geochemistry; phase equilibria, solid state theory, theory of electrolytes and transport phenomena. Lecture, 3 hours; laboratory, 2 hours. Prerequisite: Calculus, General Chemistry, Qualitative and Quantitative Analysis, Introduction to Physical Chemistry and/or permission of instructor.

### 523. GEOCHEMISTRY

Distribution of chemical elements and significant compounds in nature, and their major and minor cycles. Geochemical processes in the lithosphere, the atmosphere, and the ocean. The chemical interrelations between organisms and their environment. Lecture, 3 hours; seminar, 1½ hours. Prerequisite: Geology 101, Chemistry 110 or 111 and 112, and permission of instructor.

### 532. RADAR METEOROLOGY

The essential fundamentals of radar; the operational and research uses of radar meteorological data, their derivation from radarscope interpretation, and actual radar operation. Laboratory required. Prerequisite: Geography 311 or its equivalent, and permission of instructor. Offered in alternate years.

### 533. DYNAMIC METEOROLOGY

The thermodynamic and hydrodynamic principles for the understanding of the physical behavior of the atmosphere and its motions. Lecture, 3 hours. Prerequisite: Geography 311; Mathematics 211, 212 and Physics 235. By announcement.

### 552. MARINE FIELD GEOLOGY

An intensive, full-time five-week course emphasizing field observation and lab interpretation of shallow and deep water marine geological phenomena. Stressed are analyses of recent and fossil reef development and carbonate sedimentary patterns in South Florida and Bahamas. Data reduction, oceanographic trips. SCUBA training provided; swimming ability necessary. Limited to 12 students. Prerequisite: General and Historical Geology, Geological Mapping, and permission of the instructor.

### 551. MARINE GEOLOGY

The Earth as a planet and its chemical differentiation. Gravity, isostasy, heat flow, and seismic waves. The terrestrial magnetic fields and its components. Continental and oceanic crust; structural features and evolution through time. Submarine geomorphology and sedimentation, with emphasis on deep-sea sediments and their stratigraphic record. Lecture, 3 hours; laboratory, 2 hours; field trips as required. Prerequisite: Geology 312 or permission of instructor.

561. GEOPHYSICS

The physical properties of the interior of the Earth, with emphasis on seismology, magnetism, and gravimetry. The interrelation between land, ocean and atmosphere. Lecture, 3 hours; seminar, 1½ hours. Prerequisite: Geology 101, Physics 212, and permission of instructor.

581, 582. SUPERVISED PROJECTS

Students engaging in certain approved field activities, such as active participation in expeditions under proper supervision, may register for credit. Prerequisite: Permission of department.

## Graduate Studies

601. MARINE SCIENCE SEMINAR

Required of all majors in oceanography, fisheries, and marine biology.

602. PHYSICAL OCEANOGRAPHY SEMINAR

Required of all majors in oceanography.

603. SPECIAL WORK

Special work to enrich the student's background according to qualification requirements. May not count toward the degree. Offered only when warranted by need. Prerequisite: Permission of department chairman.

611. OCEANIC CIRCULATION AND DYNAMIC OCEANOGRAPHY

Dynamics of ocean circulation; the Gulf Stream; Equatorial current system; thermohaline circulation; the thermocline; turbulent diffusion; estuarine circulation. Lecture, 3 hours; problem session, 1 hour. Prerequisite: 512, and partial differential equations.

612. WAVES AND TIDES

Development of the basic equations governing wave motions. Surface and internal waves. Seiches; tides, planetary waves; refraction; the energy spectrum; dispersion; wind generation of surface waves. Lecture, 3 hours; problem session, 1 hour. Prerequisite: 512, and partial differential equations.

613. UNDERWATER ACOUSTICS

The material will cover the general theory of reflection and refraction, the eikonal equations, wave and ray theory with applications, normal modes, sound propagation in deep and shallow water, the effect of medium irregularities, ocean measurements in terms of filter theory, signal processing, and recent advances in underwater acoustics. Prerequisite: Ocean Engineering 535, or permission of instructor.

630. ADVANCED SEDIMENTATION

Advanced studies in the processes and products of sedimentation with special emphasis upon the mechanics of sediment transport, deposition and subsequent modification. Includes studies of texture, structures and composition of ancient and modern sediments. Lectures, 3 hours; laboratory and field trips required. Prerequisite: 501 and Optical Mineralogy.

651. MORPHOLOGY AND STRUCTURE OF OCEAN BASINS

Origin and structure of ocean basins, ridges, rises, and continental margins and their morphological features. Theory, practice, and evaluation of descriptive and quantitative procedures of defining criteria and mechanics of major and minor oceanic features. Lecture, 3 hours; laboratory, 2 hours. Prerequisite: Physical Geology and permission of instructor.

671-673. ADVANCED STUDY IN MARINE PHYSICAL SCIENCES

Supervised study of special interest to graduate students. Prerequisite: Permission of department.

Person to be contacted for further information:

Edwin S. Iversen, Chairman
Division of Graduate Studies
in Marine Science
Institute of Marine Sciences
University of Miami
1 Rickenbacker Causeway
Miami, Florida 33149

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## UNIVERSITY OF GEORGIA
Athens, Georgia 30601

## UNIVERSITY OF GEORGIA MARINE INSTITUTE

Since its founding in 1953, the Marine Institute, located on Sapelo Island, Georgia, has served the University as a primary base for research and graduate training in the marine sciences. The Institute has a permanent resident staff of seven scientists plus supporting personnel. The resident staff members are primarily engaged in research, but are also active in graduate and post doctoral training, and on occasion participate in courses on the Athens campus. The facilities of the Institute are frequently used by visiting classes from the University of Georgia and from other institutions, but no formal courses are offered there on a regular basis at present. All Institute staff members are co-staffed in appropriate academic departments, and, where applicable, are affiliated with Athens-based Ecology Institute. Many of the University staff and graduate students are actively engaged in research at the Marine Institute and elsewhere. Visiting scientists and graduate students from other institutions are encouraged and accommodated wherever possible.

Facilities for training and research in the marine sciences at Athens include laboratories in the Departments of Bacteriology, Biochemistry, Botany, Chemistry, Geology, and Zoology. At Sapelo Island, modern, well equipped laboratories occupy more than 10,000 square feet of space. Living accommodations on the Island include fifteen housing units and dormitory space for eighteen. The principal research vessel of the Institute is 65 feet in length and is equipped to carry out investigations on the continental shelf and slope as well as in the estuaries. A fleet of small boats is maintained for work in the extensive estuaries and salt marshes of the area.

Research at the Institute has centered mainly in the ecology of marshes and estuaries, the geochemistry of estuaries and shelf waters and the geology of the barrier islands and pleistocene shelf deposits. Recently formed ties with the Georgia Game and Fish Commission will augment the basic research program of the Institute with studies of fish and shellfish.

Instructional Staff: (Athens)

ROGER A. BARNHART, Unit Leader, Coop. Fishery Unit, USFWS Fisheries Biology
ROBERT E. CARVER, Assistant Professor of Geology, Sedimentary Petrology
WILBUR H. DUNCAN, Professor of Botany, Plant Taxonomy, Salt Marsh Ecology
ROBERT G. EAGON, Professor of Bacteriology, Bacterial Physiology
JOHN F. KERR, Assistant Professor of Zoology, Fish Biology, Ichthyology, Fish Behavior
EUGENE P. ODUM, Alumni Foundation, Distinguished Professor of Zoology, Bioenergetics of Ecosystems, Estuarine Ecology
WILLIAM J. PAYNE, Professor of Bacteriology, Intermediary Metabolism of Marine Bacteria
LAWRENCE R. POMEROY, Professor of Zoology, Biological Oceanography, Biogeochemistry of Phosphorus
LAWRENCE D. RAMSPOTT, Assistant Professor of Geology, Geotectonics, Structural Geology
MARK RICH, Associate Professor of Geology, Carbonate Petrology, Paleontology
DONALD C. SCOTT, Professor of Zoology, Fish Biology, Limnology, Estuarine Ecology
JAMES A. SHEAR, Professor of Geography, Meteorology, Climatology
EDWARD A. STANLEY, Assistant Professor of Geology, Paleontology, Palynology
GRACE J. THOMAS, Associate Professor of Geology, Invertebrate Zoology, Malacology
MICHAEL R. VOORHIES, Assistant Professor of Geology, Marine Paleoclimatology, Vertebrate Paleontology

Resident Staff: (Sapelo Island)

MICHAEL D. DAHLBERG, Assistant Professor of Zoology, Ichthyology
DIRK FRANKENBERG, Assistant Professor of Zoology, Estuarine Ecology, Marine Benthos
VERNON J. HENRY, Associate Professor of Geology, Marine Geology, Geophysics
JAMES D. HOWARD, Assistant Professor of Geology, Marine Geology, Paleontology
JOHN H. HOYT, Assistant Professor of Marine Geology, Sedimentation
THOMAS L. LINTON, Research Associate, Biology of Shrimp and Oysters

Degrees Offered:

Students at the undergraduate level cannot specialize in marine science but are required to obtain a broad background in the physical and biological sciences. The M.S. and Ph.D. degrees are offered in basic science departments (Bacteriology, Biochemistry, Botany, Geology, and Zoology) with emphasis on the various marine aspects of each. The offering of a specific degree in oceanography has not been deemed essential to the training program, but is currently under consideration.

Courses Offered:

Only advanced courses with marine aspects are listed here, courses numbered 800 and above are strictly graduate, others are senior-graduate.

Department of Bacteriology

860 PHYSIOLOGY OF BACTERIA
Eagon

Survey of the physiology and metabolism of microorganisms.

900 PROBLEMS IN BACTERIOLOGY
Staff

Department of Botany

802 PROBLEMS IN BOTANY
Staff

860 AQUATIC PLANTS
Duncan

Taxonomy, distribution and ecology of aquatic plants.

Department of Geography

601 ADVANCED CLIMATOLOGY
Shear

Intensive systematic studies of climatic factors of atmospheric heat and moisture and studies of great controls affecting world climatic patterns.

602 NORTH AMERICAN PHYSIOGRAPHY
Woodruff

Distinctive terrain characteristics of North American surface topography.

620 USE AND INTERPRETATION OF AERIAL PHOTOGRAPHS
Maxfield

Use of aerial photography as an analytical and research tool.

622 ADVANCED PHOTOGRAMMETRY LABORATORY
Masfield

Detailed analysis of photo metrics and instruments in photogrammetry. Execution of a research project is required.

Department of Geology

603 INVERTEBRATE PALEONTOLOGY
Stanley

A systematic review of living and extinct invertebrate groups. Anatomy, classification and geologic history of major invertebrate phyla.

605 SEDIMENTATION AND STRATIGRAPHY
Rich

The origin and distribution of sedimentary rocks. Environments and mechanisms of transportation and deposition of sediments. Sequence and correlation in sedimentary rocks.

608 OPTICAL MINERALOGY
Hurst

Identification of minerals by optical methods, using the polarizing microscope. A necessary prerequisite to all sedimentological studies.

609 MARINE GEOLOGY
Henry, Hoyt

Structure and geomorphology of the ocean floor and shorelines. Marine sediments and sedimentation processes. Chemistry and physics of seawater as an environmental medium.

610 SEDIMENTARY PETROLOGY
Carver

Derivation of sediment materials. Alteration of sediment materials through weathering, transport and diagenesis. Determination of environments of deposition.

611 PRINCIPLES OF GEOCHEMISTRY
Salotti

Distribution of elements in minerals, rocks and waters. Principles governing the migration and concentration of elements. Introduction to the use of radionuclide tags and tracers.

612 PALYNOLOGY
Stanley

The application of pollen and spore analysis to a broad spectrum of problems, including marine geology. Practical experience in extraction and identification and interpretation of pollen and spore diagrams.

613 PALEOBOTANY
Stanley

A systematic review of the history of the major plant groups. Phylogeny and taxonomy of recent and fossil plants. The use of plant fossils in paleoclimatology, paleoecology, and stratigraphy.

630 CLAY MINERALOGY
Hurst

Crystal structure and properties of clay minerals. Effect of environmental factors on their origin and diagenesis. Identification of clay minerals by optical and x-ray methods.

805 ADVANCED STRATIGRAPHY
Rich

Major concepts in lithostratigraphy and biostratigraphy. Major stratigraphic sequences of North America.

811 PETROGRAPHY AND PETROLOGY OF SEDIMENTARY ROCKS
Rich

Microscopic study of sedimentary rocks. Interpretation of textures, structures and mineral associations at the advanced level.

815 SPECIAL PROBLEMS IN SEDIMENTOLOGY AND OCEANOGRAPHY
Staff

Intensive study on approved problems in sedimentology and oceanography, under the direction of one or more staff members.

820 GEOTECTONICS
Ramspott

Recent experimental and theoretical developments in tectonics. Origin and permanence of continents and ocean basins, geosynclinal theory, isostasy.

Department of Zoology

600 ENERGETICS AND ECOSYSTEMS
Odum, Staff

Principles of energetics as applied to ecological systems.

605 ICHTHYOLOGY
Scott, Dahlberg

Taxonomy, distribution, evolution and ecology of fishes with special reference to marine and freshwater fishes of eastern North America.

807 ADVANCED INVERTEBRATE ZOOLOGY
Thomas

808 ADVANCED INVERTEBRATE ZOOLOGY
Thomas

Morphology, phylogeny and general biology of the invertebrate phyla.

810 LIMNOLOGY AND OCEANOGRAPHY
Pomeroy, Scott

The physics, chemistry and biology of lakes, streams and oceans.

811 MARINE BIOLOGY
Pomeroy

Populations of the oceans, their interactions and relations to the environment.

812 FRESHWATER BIOLOGY
Scott

Identification, natural history and environmental relationships of freshwater organisms.

813 HYDROBIOLOGY SEMINAR
Pomeroy, Scott

Recent advances in marine and freshwater biology.

854 PHYSIOLOGICAL ECOLOGY
Odum

Environmental factors affecting organisms, physiological basis for animal behavior.

855 ADVANCED ECOLOGY
Odum

Advanced consideration of ecological principles with emphasis on population ecology.

856 ECOLOGY SEMINAR
Odum, Staff

Recent advances in ecology, integrating ideas and data from current plant, animal and microbial research.

857 POLLUTION ECOLOGY
Odum, Pomeroy, Scott

Consideration of ecological aspects of environmental pollution based on the ecosystem concept and with particular emphasis on aquatic systems.

900 PROBLEMS IN ZOOLOGY
Staff

Person to be contacted for further information:

Dr. R. A. McRorie
Director
General Research
University of Georgia
Athens, Georgia 30601

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## UNIVERSITY OF HAWAII
Honolulu, Hawaii 96822

The laboratory and classroom facilities of the Department of Oceanography are located in the Hawaii Institute of Geophysics on the Manoa campus of the University of Hawaii. In the same building and available for use by the Department are the Geophysics Library and the Statistical and Computing Center containing IBM 1401 and 7040 computers.

The Department is closely associated with the Hawaii Institute of Geophysics, a geophysical research institute that, in cooperation with various departments, provides research facilities and appointments in astrophysics, geochemistry, geology, meteorology, oceanography, and geophysics. The Institute also maintains a high-altitude observatory on the summit of Mount Haleakala, Maui, and a seismic vault in upper Manoa Valley.

Other facilities that are available to the Oceanography Department are the Hawaii Marine Laboratory, an ocean-side laboratory on the east coast of Oahu devoted to advanced training, research, and instruction in marine biology; Gregg M. Sinclair Library, the main library of the University; and the Honolulu Biological Laboratory of the U.S. Fish and Wildlife Service a major oceanographic biological research institute located on the University campus.

The marine facilities of the Department are located at Kewalo Basin, Honolulu, a ten minute drive from the University. These include storage buildings, repair shops and docking facilities for the University's research vessel, TERITU, and the various smaller boats used for nearshore research.

The TERITU is a 90-foot steel-hulled research vessel converted and over-hauled in 1964 and equipped with the latest oceanographic equipment. She has approximately 480 square feet of electronic and wet laboratory space and well-furnished quarters for six scientists. Smaller boats include a 46-foot decked boat, the SALPA. Two larger research vessels belonging to the U.S. Fish and Wildlife Service are available for use in cooperation with that agency's research program: the GILBERT, 122 feet, and the newly constructed CROMWELL, 158 feet.

Instructional Staff:

RICHARD G. BADER, Ph.D., Chairman, Professor, Chemical Oceanography
VERNON E. BROCK, M.A., Professor, Biological Oceanography
THEODORE CHAMBERLAIN, Ph.D., Associate Professor, Geological Oceanography
KEITH E. CHAVE, Ph.D., Professor, Geological Oceanography
ROBERT I. CLUTTER, Ph.D., Assistant Professor, Biological Oceanography
WALTER DUING, Ph.D., Assistant Professor, Physical Oceanography
BRENT GALLAGHER, Ph.D., Assistant Professor, Physical Oceanography

VOLKER GRAEFE, Ph.D., Assistant Professor, Physical Oceanography
GORDON W. GROVES, Ph.D., Professor, Physical Oceanography
ALEXANDER MALAHOFF, Ph.D., Assistant Professor, Geological Oceanography
GARTH I. MURPHY, Ph.D., Professor, Biological Oceanography
BRIAN PASBY, Ph.D., Assistant Professor, Chemical Oceanography
EDWARD D. STROUP, M.S., Associate Professor, Physical Oceanography
KLAUS WYRTKI, Ph.D., Professor, Physical Oceanography

## Affiliate Graduate Faculty

RICHARD A. BARKLEY, Ph.D., Lecturer
JOHN C. MARR, M.A., Lecturer
GUNTER R. SECKEL, M.S., Lecturer

## Degrees Offered:

M.S. in Oceanography
Ph.D., in Oceanography (Tentatively scheduled for 1 September 1967)

## Courses Offered:

## Department of Oceanography

### Undergraduate Courses

**Ocn. 201 SCIENCE OF THE SEA**
Chamberlain

Introduction to biological, geological, chemical, and physical aspects of oceanography. Based on classroom lectures and the use of oceanographic equipment and techniques at sea, aboard ship and in the nearshore zone.

### Graduate Courses

**Ocn. 620 PHYSICAL OCEANOGRAPHY**
Wyrtki

Introduction to the properties of seawater, oceanographic instruments and methods, the heat budget, general ocean circulation, the formation of water masses, the dynamics of the circulation, regional oceanography, waves, tides, and sea level. Prerequisite: Math 136.

**Ocn. 621 BIOLOGICAL OCEANOGRAPHY**
Brock

Marine organisms, factors governing productivity; distribution, ecology, environmental influences; marine resources, their availability and utilization. Desirable preparation: 620.

**Ocn. 622 GEOLOGICAL OCEANOGRAPHY**
Chamberlain

Marine geological processes and forms, including ocean basin structure and geomorphology, nearshore processes, and marine sedimentation and stratigraphy. Prerequisite: 620.

**Ocn. 623 CHEMICAL OCEANOGRAPHY**
Pasby

Study of the chemical processes in marine waters including composition of sea water, nutrients, extraction of materials, carbon dioxide systems. Desirable preparation: 620.

**Ocn. 631 MARINE PHYTOPLANKTON**

Identification, systematic morphology, distribution and abundance. Desirable preparation: 620.

**Ocn. 632 LITTORAL GEOLOGICAL PROCESSES**
Chamberlain

Geological processes and forms peculiar to the nearshore marine environment. Prerequisite: 620, 622.

**Ocn. 633 CHEMICAL OCEANOGRAPHY LABORATORY METHODS**
Pasby

Standard chemical methods of analysis. Prerequisite: Chem. 331 or consent of instructor.

**Ocn. 636 PHYTOPLANKTON ECOLOGY**

Phytoplankton-environmental relations and community ecology; phytoplankton-zooplankton interactions; plankton community synecology. Prerequisite: 620, 631 or consent of instructor.

**Ocn. 640 ADVANCED PHYSICAL OCEANOGRAPHY**
Wyrtki

Dynamics of ocean currents; equations of motion and continuity; ocean circulation; heat budgets. Prerequisite: 620, Math 402.

**Ocn. 641 MARINE ZOOPLANKTON**
Clutter

Systematic morphology, identification and classification of major groups of mid-Pacific zooplankton, exclusive of protozoa. Prerequisite: Zool. 205 or consent of instructor.

**Ocn. 642 RECENT MARINE SEDIMENTS**
Staff

Composition and distribution of recent marine sediments. Marine sedimentary environments. Prerequisite: 623, 622.

**Ocn. 643 MARINE GEOCHEMISTRY**
Staff

Origin and history of the oceans, isotope geochemistry, sedimentary cycle, biogeochemistry. Prerequisite: 622, 623.

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Ocn. 644 MARINE GEOLOGIC AND GEOPHYSICAL TECHNIQUES
Malahoff

Applications of established sea-borne geological and geophysical exploration techniques to study the composition and configuration of the ocean floor and the sub-bottom structure. Use of physiographic and structural interpretation techniques. Prerequisite: 622 and consent of instructor.

Ocn. 646 ZOOPLANKTON ECOLOGY
Clutter

Sampling, distributing patterns, population dynamics, community structure, and energy flow in the pelagic environment. Prerequisite: consent of instructor; 620, 641.

Ocn. 651 DYNAMICS OF MARINE PRODUCTIVITY

Primary productivity, its variation and methods of assessment; conversion of energy in food chains, ecosystems; factors affecting productivity. Prerequisite: 621.

Ocn. 660 OCEAN WAVE THEORY
Groves

Generation and propagation of waves at sea; tsunamis; internal waves; observation and recording of ocean waves; wave spectra and forecasting. Prerequisite: either 640, Math 432, or consent of instructor.

Ocn. 661 TIDES
Groves

Mechanics of particles and finite bodies; tide-generating forces; response of ocean and earth; harmonic and non-harmonic methods of analysis and prediction; geophysical implications of the tide. Prerequisite: either 640, Math 432, or consent of instructor.

Ocn. 662 MARINE HYDRODYNAMICS
Gallagher

Introduction to classical hydrodynamics and the development of the Navier-Stokes equations as applied to the oceans. Techniques for solution on various scales of oceanic motion, including turbulence; potential theory, dimensional analysis, vertical integration, boundary effects and statistical representations. Prerequisite: Math 432 or consent of instructor.

Ocn. 633 MEASUREMENTS AND INSTRUMENTATION
Graefe

Oceanographic measurements; their accuracy and precision. Design principles, and operation of selected instruments for physical oceanography. Reduction and evaluation of measured data.

Ocn. 672 OCEAN BASINS
Staff

Origin, structure, and geomorphology of the ocean basins. Prerequisite: 622.

Ocn. 699 DIRECTED RESEARCH
Staff

Prerequisite: approval of instructor.

Ocn. 701 NEKTON ECOLOGY
Murphy

Relationship of larger ocean animals to the physico-biological environment and to each other. Patterns of life history as related to environment, problems of exploitation, and response to exploitation. Prerequisite: 641 and Zool. 631 or consent of instructor.

Ocn. 735 SEMINAR IN OCEANOGRAPHY
Staff

Ocn. 750 TOPICS IN BIOLOGICAL OCEANOGRAPHY
Staff

Seminar. Literature and concepts in one of several active fields of biological oceanography considered in detail. May be repeated for credit. Prerequisite: consent of instructor.

Ocn. 799 SEMINAR
Staff

Student presentations based on literature reviews and research. Prerequisite: approval of graduate advisor.

Ocn. 800 THESIS RESEARCH
Staff

### Department of Botany

### Undergraduate Courses

Botany 480 PHYCOLOGY
Doty

Morphology, taxonomy and ecology of algae. Identification of common algae.

Botany 651 BIOLOGICAL PRODUCTIVITY OF THE SEA
Doty

Primary productivity, its variation and methods of assessment; conversion of energy in food chains, ecosystems; factors affecting productivity. Prerequisite: graduate standing or instructor's permission.

### Graduate Courses

Botany 631 MARINE PHYTOPLANKTON
Doty

Identification, systematic morphology, distribution and abundance. Prerequisite: graduate standing or permission of instructor.

Botany 681 PHYCOLOGY-CHLOROPHYTA
Doty

Systematics, functions, and utilization considered at an advanced level. Prerequisite: graduate standing in biology.

Botany 682 PHYCOLOGY-PHYTOPLANKTON
Doty

Systematics, functions, and utilization considered at an advanced level. Prerequisite: graduate standing in biology.

Botany 683 PHYCOLOGY-MYXOPHYTA AND PHAEOPHYTA
Doty

Systematics, functions, and utilization considered at an advanced level. Prerequisite: graduate standing in biology.

Botany 684 PHYCOLOGY-RHODOPHYTA
Doty

Systematics, functions, and utilization considered at an advanced level. Prerequisite: graduate standing in biology.

Person to be contacted for further information:

Richard G. Bader
Chairman
Department of Oceanography
University of Hawaii
Honolulu, Hawaii 96822

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## ILLINOIS TEACHERS COLLEGE CHICAGO-NORTH
Chicago, Illinois 60624*

The oceanography program, offered cooperatively by the Department of Geography and the Department of Physical Sciences, stresses a broad approach to oceanography at both the undergraduate and graduate level. New facilities are planned and construction is due to start in 1967. Coastal aspects of oceanography are taught during a summer "field" program operated in Ensenada (Baja California, Mexico) through special arrangements with the Escuela Superior de Ciencias Marinas of the Universidad Autonoma de Baja California. The GP-4 of the Mexican Coast Guard provides shipboard experience. Students are furthermore encouraged to attend summer sessions at oceanographic stations.

Instructional Staff:

ROGER H. CHARLIER, Ph.D., Professor of Geology, Geography and Oceanography
ROBERT F. BETZ, Ph.D., Professor of Biology
C. WALLACE DIERICKX, Ph.D., Professor of Geography
ROBERT J. GOLDBERG, Ph.D., Professor of Biology
FLOYD J. WIERCINSKI, Ph.D., Professor of Biology
CLARENCE B. ODELL, Ph.D., visiting Professor of Cartography
WILLIAM L. HOWENSTINE, Ph.D., Associate Professor of Conservation
AL FORSLEV, Ph.D., Associate Professor of Earth Sciences
YING-CHENG KIANG, Ph.D., Associate Professor of Geography
CARROLL SCHWARTZ, M.A., Assistant Professor of Geography

Degrees Offered:

The College does not offer a program leading to undergraduate or advanced degrees in the marine sciences. The undergraduate student, interested in oceanography, may follow a program leading to a B.S. degree in the earth sciences or geography, with concentration in oceanography. The graduate student may obtain an M.A. in geography, geology or earth sciences with concentration in oceanography.

Courses Offered:

Undergraduate

41-318 CONSERVATION OF NATURAL RESOURCES
Howenstine

Concepts and principles in the management of natural resources; air, water, minerals, soil, forests, grasslands, and wildlife.

53-211 PHYSICAL GEOLOGY
Charlier, Forslev

Detailed study of the materials composing, and forces governing the crust and interiors of the earth; theories on the origin and distribution of continents, ocean basins, and mountain ranges in the light of recent geological and geophysical research.

53-272 FUNDAMENTALS OF METEOROLOGY AND CLIMATOLOGY
Kiang

The study of the atmosphere, its composition and function, its response to isolation, problems in the upper atmosphere, interactions along atmospheric boundaries, weather phenomena, introduction to climate and its effects. Prerequisite: Physical Science I or Physics I.

53-313 STRATIGRAPHY AND SEDIMENTOLOGY
Charlier, Forslev

Formation, composition, sequence, and correlation of stratified rocks of the earth's crust; sedimentary rocks and the process by which they were formed. Prerequisite: Historical Geology.

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* To be known as Northeastern Illinois State College as of September 1967.

53-318 WORLD REGIONAL GEOLOGY
Staff

Introduction to the comparative structure, stratigraphy, and geologic evolution of the continents, with emphasis on North America and Europe. Prerequisite: Historical Geology.

53-321 OCEANOGRAPHY
Charlier

Physical and biological oceanography. Physics and chemistry of sea water; ocean boundaries and bottom topography; hydrodynamics--currents, tides, waves; relationship to marine biology.

53-324 HISTORY OF THE GEOLOGICAL SCIENCES
Staff

Growth of key concepts in geology and related sciences and the men who were responsible for them. (May be offered as history of oceanography.)

53-325 SEMINARS IN EARTH SCIENCE
Staff

Selected topics of current research interest. 1 hour seminar discussion. Prerequisite: Advanced standing with major concentration in earth science, or consent of instructor.

53-326 INDIVIDUAL STUDY IN EARTH SCIENCE
Staff

Research in geology, physical geography, oceanography or meteorology. Prerequisite: Consent of instructor.

Graduate (Open to Seniors)

43-392 PALEOGEOGRAPHY
Staff

Study of past environments and past climates. Shorelines. Sea-level.

43-393 CLIMATOLOGY
Kiang

Advanced study of climates and their geographical distribution. Air-sea relationships.

43-394 PHYSICAL OCEANOGRAPHY*
Charlier

Movements of the sea. Physical factors. Temperature of sea waters. Circulation. Chemical composition and properties of sea water. Salinity. Physical and chemical properties.

43-395 GEOLOGICAL OCEANOGRAPHY*
Charlier

Structure, morphology, and history of ocean basins. Marine erosion and sedimentation. Marine sediments and their geographical distribution. Coastal geology.

43-396 BIOLOGICAL OCEANOGRAPHY*
Wiercinski

Conditions of life in the ocean. Life cycle. Population zones. Study of major groups.

43-352 GUIDED STUDY IN GEOGRAPHY - OCEANOGRAPHY
Charlier

Special study and intense laboratory and shipboard work; subject to approval of the instructor.

43-373 BIOLOGICAL GEOGRAPHY
Betz

Geographical distribution of living organisms and the principles underlying this distribution.

43-374 CARTOGRAPHY
Odell

Mapping techniques. Projections. Surveying. Laboratory exercises. Instruction and practice.

43-390 MATHEMATICAL GEOGRAPHY
Odell

Theory of map making. Isostasy. Orogenic theories. Geodesy.

43-391 QUANTITATIVE MEASUREMENTS
Charlier

Advanced statistical techniques in earth and marine sciences. Time series. Non-parametric statistics. Multivariate analysis. Exercises. Prerequisite: 53-401.

53-401 STATISTICS FOR EARTH SCIENCES
Charlier

Statistical methods and processes as they apply to geology, oceanography, meteorology and geography.

43-431 THESIS SEMINAR
Staff

56-317 ECOLOGY
Goldberg

Basic principles applicable to interrelationships between living things and their environment, their exemplification by observation in the field. The current danger of disturbing balances generally in nature and by environment contamination. Prerequisite: 2 semesters of biology or consent of instructor.

Person to be contacted for further information:

Dr. Roger H. Charlier, Director
Oceanography Programs
Illinois State Teachers College
5500 No. St. Louis Avenue
Chicago, Illinois 60625

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* Final approval pending.

* Final approval pending.

## THE UNIVERSITY OF CHICAGO
Chicago, Illinois 60637

### DEPARTMENT OF THE GEOPHYSICAL SCIENCES

The University of Chicago is expanding its activities in oceanography and hopes to offer more courses in marine science than at present. However, the principal emphasis will be on thorough preparation in basic disciplines with opportunities to apply them to marine research through affording students opportunity to participate in research at marine laboratories.

At the present time, research at the University is being conducted on storm surges, nearshore oceanic circulation, interaction of waves and bottom, geochemistry of marine sediments, interactions between marine organisms and their environment and the organization of marine communities. Facilities at the University include a wave tank, flume, wind tunnel, paleocology laboratory, sedimentology laboratory, geochemistry laboratories, hydrodynamics laboratory, electron probe, x-ray diffraction equipment and several high speed computers. Field facilities are available at the Woods Hole Oceanographic Institution and the Pacific Marine Station.

Instructional Staff:

LAWRENCE F. McGOLDRICK, Ph.D., Assistant Professor of Fluid Mechanics
DAVE FULTZ, Ph.D., Professor of Meteorology
JOEL W. HEDGPETH, Ph.D., Oregon State University, Marine Science Laboratory
RALPH G. JOHNSON, Ph.D., Associate Professor of Paleontology
ROBERT L. MILLER, Ph.D., Professor of Marine Geophysics.
GEORGE W. PLATZMAN, Ph.D., Professor of Meteorology
JAMES M. WITTING, Ph.D., Assistant Professor of Hydrodynamics
JOHN ZEIGLER, Ph.D., Woods Hole Oceanographic Institution, Lecturer in Marine Geology
WILLIAM H. REID, Ph.D., Professor of Applied Mathematics

Degrees Offered:

None in oceanography. The M.S. and Ph.D. degrees in the geophysical sciences are offered with specialization in areas included in oceanography.

Courses Offered:

131 INTRODUCTION TO THE GEOPHYSICAL SCIENCES I
Elders, Johnson

The earth as a planet. Origin and evolution of the solar system. Chemistry and physics of the earth's interior and crust. Physical and biological oceanography.

200 INTRODUCTION TO FLUID MECHANICS
Miller

An introductory, one-quarter survey of fluid mechanics. Lecture plus problem session. Ideal fluid, turbulence, boundary layer; includes some discussion of compressible fluids and application of thermodynamics.

201, 202, 203 FLUID MECHANICS I, II, III
McGoldrick

This sequence is intended to prepare the student for most of the advanced fluid mechanics and geophysical fluid mechanics courses. Kinematics, equations of motion; energy and momentum consideration; fluid statics and surface tension; vorticity theorems; potential flows and conformal mapping; surface and internal waves; rotating flows; viscous flows at low Reynolds numbers; boundary layer approximations; stability; electromagnetic effects.

280 INTRODUCTION TO GEOPHYSICAL DYNAMICS
Hines, Platzman, Kuo

Basic principles of hydrodynamics of a rotating fluid. Theorems of vorticity and circulation and their applications. Simple wind systems. Planetary boundary layer.

281 WAVES IN THE ATMOSPHERE
Hines, Platzman

Acoustic waves, including infrasonics; gravity waves including mountain waves, upper-atmosphere motions, atmospheric tides; rotational waves, including inertia waves, baraclinic waves, planetary waves.

282 WAVES IN THE OCEAN
Platzman

Acoustic waves, gravity waves including wind waves, edge waves, oscillations on shelves and in bays, tsunamis, ocean tides; rotational waves.

Graduate Courses

301 BOUNDARY-LAYER THEORY
Reid

Derivation of the boundary-layer equations; relationship to singular perturbation theory. Exact solutions, similarity solutions, approximate solutions. Boundary currents in the oceans.

302 HYDRODYNAMIC STABILITY
Reid

Thermal instability; stability of curved flows; stability of parallel flows; exact solutions; methods of approximation. Effects of rotation and density stratification.

303 TURBULENCE
Reid

Homogeneous and isotropic turbulence, mostly Batchelor, some Kraichnan; scattering; diffusion; dispersion; shear flows.

305 EXPERIMENTAL HYDRODYNAMICS
Fultz

Experimental and theoretical topics in small-scale geophysically motivated experiments, such as vortex streets in wakes, rotating and non-rotating Benard convection, vertical-plate thermal boundary-layer flows, finite-amplitude effects and damping of surface waves, drag in rotating fluids, Ekman layers in rotating fluids.

343 OCEAN WAVE THEORY
McGoldrick

Review of classical results; generalized Fourier analysis; specification of a random sea; ocean wave spectra; perturbations to irrotational motion; some exact results; non-linear theories; resonant interactions; wave generation by the wind.

344 STORM SURGES
Platzman

Observations and theories of transient fluctuations of water level produced by traveling wind and pressure systems of small and large scale on the continental shelf and in inclosed seas.

348, 349 SHALLOW-WATER OCEANOGRAPHY I, II
Miller

Coastal processes and dynamics of estuarine and coastal waters.

385, 386 SEMINAR: SEDIMENT TRANSPORT I, II
Miller

381 TIDES OF THE GEOSPHERE
Platzman

Observations and theories of the primary tidal phenomena of the oceans, atmosphere and solid earth.

404 RESEARCH IN FLUID MECHANICS
McGoldrick

442 RESEARCH IN DISPERSIVE WAVES
Witting

461 RESEARCH IN DYNAMICAL PREDICTION
Platzman

462 RESEARCH IN HYDRODYNAMICAL MODELS
Fultz

463 RESEARCH IN EXPERIMENTAL HYDRODYNAMIC STABILITY
Fultz

466 RESEARCH IN THEORETICAL FLUID MECHANICS
Reid

481 RESEARCH IN MARINE GEOPHYSICS
Miller

Person to be contacted for further information:

Dr. Julian R. Goldsmith
Department of the Geophysical Sciences
The University of Chicago
1101 East 58th Street
Chicago, Illinois 60637

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## UNIVERSITY OF ILLINOIS
Urbana, Illinois 61801

### DEPARTMENT OF GEOLOGY

Illinois is considered the birthplace of submarine geology in the United States because it was here that Professor Francis P. Shepard began his marine geological investigations while he was on the staff from 1922 to 1945. While the present instructional program is in marine geology, an opportunity exists for research in marine geotechnique in cooperation with the Department of Civil Engineering.

Current marine geoscience research includes investigations of the structure and evolution of the continental margin; mass physical and engineering properties of deep-sea sediments, emphasizing measurements made by in-place telemetering probes; sedimentary structures within core tubes studied by stereo x-radiography and electronic fluoroscopy; modern and fossil estuarine ostracoda; nannofossil biostratigraphy of deep-ocean basins; and calcification in living foraminifera using electron microscopy and $Cs^{40}$ autoradiography.

Departmental facilities are modern and well-equipped for graduate training and research in the marine geosciences, in marine geotechnique, and in ancillary disciplines. Special facilities include a high-pressure laboratory, an electron microscope and vacuum evaporator, nuclear and x-ray nondestructive measuring equipment, shared use of an electron probe, underwater cameras and television, advanced-design coring equipment, and a large sediment-core refrigerator. The Geology Library has an unusually good collection of oceanographic books and expedition reports; it regularly receives about 1,300 journals in the earth sciences and oceanography.

Investigations of the deep sea are made from Coast and Geodetic Survey oceanographic ships as part of a cooperative program with the Institute for Oceanography of ESSA. Shallow-sea studies have been made using the Departmental "Boston Whaler" and a Coast Guard oceanographic research vessel.

Instructional Staff:

ALBERT V. CAROZZI, Ph.D., Professor, Carbonate Sedimentary Petrography
ROBERT S. DIETZ, Ph.D., Visiting Lecturer, Marine Geology
FRED A. DONATH, Ph.D., Professor and Head of the Department, Structural Geology and High-pressure Geophysics
WILLIAM W. HAY, Ph.D., Associate Professor, Micropaleontology and Biostratigraphy
ADRIAN F. RICHARDS, Ph.D., Associate Professor (Geology and Civil Engineering), Marine Geology and Sedimentology
PHILIP A. SANDBERG, Ph.D., Assistant Professor, Micropaleontology
F. MICHAEL WAHL, Ph.D., Associate Professor, Clay Mineralogy

Degrees Offered:

Master of Science and Doctor of Philosophy in Geology

Students may work in any of the numerous specialities represented by the 24-man departmental faculty, including: geochemistry, geophysics, geotectonics, mineral deposits, oceanography and ocean engineering, paleontology and stratigraphy, sedimentology, and submarine geology.

Courses Offered:

Undergraduate and Graduate Courses

350 THEORETICAL GEOPHYSICS

An introduction to the major fields of theoretical geophysics: figure of the earth, thermodynamics of the earth, gravity, seismology, magnetism, and planetary geophysics.

370 OCEANOGRAPHY
Richards

Principles of biological, chemical, geological, and physical marine science.

Selected Graduate Courses

420 PALEOECOLOGY
Hay

Interpretation of life habit of fossil organisms from skeletal morphology and associated depositional features; reconstruction of marine ecosystem relations from the study of assemblages of fossils.

425 MICROPALEONTOLOGY: FORAMINIFERA
Hay

Classification and stratigraphic correlation.

426 MICROPALEONTOLOGY: OSTRACODA
Sandberg

Morphology, classification, and stratigraphic and ecologic distribution, particularly recent and post-Paleozoic forms.

432 GEOCHEMISTRY
Wahl

A chemical approach to the interpretation of geological processes with emphasis on principles which control the distribution and migration of elements in geological environments.

437 SEDIMENTARY PETROLOGY
Richards

A study of sedimentary petrogenesis, including erosion, transportation, deposition, consolidation, diagenesis, and lithification.

438 SEDIMENTARY PETROGRAPHY
Carozzi

Microscopic study of sedimentary rocks in thin section with emphasis on textures and structures, as a basis for their detailed classification and general interpretation.

461 MINERALOGY OF CLAYS
Wahl

The composition of various types of clays; the structure and properties of the clay minerals; the origin and mode of occurrence of the clay minerals and the clay materials.

471 SUBMARINE GEOLOGY
Richards

General geology of the ocean basins and continental margins with emphasis on the geological interpretation of marine geophysical investigations.

493 PLANKTONIC MARINE MICROORGANISMS: FORAMINIFERA, COCCOLITHS, RADIOLARIA
Sandberg

Morphology, classification, and stratigraphic and geographic distribution.

493 ADVANCED MARINE GEOLOGY
Richards

A seminar on selected topics of current interest.

493 MARINE SEDIMENTOLOGY
Richards

Analysis and interpretation of mass physical and mass chemical properties of recent marine sediments.

Person to be contacted for further information:

Dr. Adrian F. Richards
Department of Geology
University of Illinois
Urbana, Illinois 61801

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## UNIVERSITY OF MAINE
Orono, Maine 04473

Presently, the University is acting upon a proposal to offer a doctoral program in oceanography. It is expected that final approval will be obtained by the summer of 1967 and that the program will begin September, 1967. The program will be administered by an interdisciplinary Oceanography Steering Committee. In addition to the main campus teaching and research facilities, a 136 acre site is under development as a marine station at Walpole (100 miles south of the campus). Present facilities consist of 3,000 square feet of laboratory space, 1,800 square feet of dormitory space, skiffs with outboards and the 43-foot R/V DRAKE. Construction of a pier and adjacent modern research laboratory is expected shortly.

Instructional Staff:

KENNETH W. ALLEN, Ph.D., Professor, Zoology
HAROLD W. BORNS, Ph.D., Associate Professor, Geology
JAMES R. COOK, Ph.D., Assistant Professor, Zoology
DAVID DEAN, Ph.D., Professor, Zoology
JOHN H. DEARBORN, Ph.D., Assistant Professor, Zoology
W. HARRY EVERHART, Ph.D., Professor, Zoology
PAUL A. HAEFNER, JR., Ph.D., Assistant Professor, Zoology
BRADFORD A HALL, Ph.D., Assistant Professor, Geology
RICHARD W. HATCH, Ph.D., Associate Professor, Zoology
CHARLES W. MAJOR, Ph.D., Associate Professor, Zoology
MARVIN C. MEYER, Ph.D., Professor, Zoology
CHARLES D. RICHARDS, Ph.D., Professor, Botany
FRANKLIN L. ROBERTS, Ph.D., Assistant Professor, Zoology
ROBERT L. VADAS, B.S. (Ph.D. anticipated 1967), Assistant Professor, Botany

Degrees Offered:

Master of Science in Bacteriology, Biochemistry, Botany and Plant Pathology, Geology, and Zoology.*

Doctor of Philosophy in Plant Science (includes Bacteriology, Biochemistry and Botany) and Zoology.*

Doctor of Philosophy in Oceanography.**

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* Students may specialize in a marine problem without entering the oceanography curriculum. Students in oceanography may specialize only in biological oceanography at present.

** Pending - subject to final approval by the Board of Trustees.

Courses Offered:

Botany and Plant Pathology

Undergraduate

163. INTRODUCTORY PHYCOLOGY
Vadas

The comparative morphology and identification of algae, plus investigation of sexuality, ecology and physiological features.

Graduate

**265. ADVANCED PHYCOLOGY
Vadas

An experimental approach to the biology of algae including detailed studies of the form, function, culture and ecology of selected groups.

399. THESIS
Staff

Zoology

Undergraduate

132. ICHTHYOLOGY
Everhart

The characteristics of fishes, their life histories and economic importance, with emphasis on freshwater species.

153. INVERTEBRATE ZOOLOGY
Meyer

The morphology, physiology, life histories, phylogenetic relationship, and economic importance of invertebrates exclusive of insects.

168. LIMNOLOGY
Hatch

The ecology of inland water, with primary emphasis on the physical, chemical and biological factors controlling productivity.

**170. INTRODUCTION TO OCEANOGRAPHY
Haefner

A synoptic study of the geology, physics, chemistry and biology of the oceans.

171. FISH MANAGEMENT
Everhart

Modern methods of fish management including propagation and distribution, fisheries legislation, biological surveys and environmental improvements.

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**Pending - subject to final approval by the Board of Trustees.

Graduate

**210. MARINE INVERTEBRATE ZOOLOGY
Staff

The morphology, functional anatomy, systematics and phylogenetic relationships of free-living marine invertebrates, excluding protozoans, with laboratory emphasis on studies of living material from the local fauna.

357. POPULATION DYNAMICS
Hatch

Methods of estimating population size, growth rate and mortality rates, production and yield. Problems of predicting population fluctuations and cycles, theories of population harvest for maximum sustained yield, and various types of yield equation.

362. ESTUARINE ECOLOGY
Haefner

Analysis of the geology, physics, chemistry, and biology of the estuarine ecosystem.

** 369. BIOLOGICAL OCEANOGRAPHY
Staff

A study of the organisms of the sea, their actions and interactions.

370. ADVANCED TOPICS IN AQUATIC BIOLOGY
Staff

A seminar type course designed to acquaint the student with current research in biological oceanography and fishery science.

**393, 394. PROBLEMS IN BIOLOGICAL OCEANOGRAPHY
Staff

Independent study of special problems.

399. THESIS Staff

Person to be contacted for further information:

Dr. David Dean, Director
Ira C. Darling Center for Research,
Teaching and Service
University of Maine
Walpole, Maine 04573

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**Pending - subject to final approval by the Board of Trustees.

## THE JOHNS HOPKINS UNIVERSITY
Baltimore, Maryland 21218

DEPARTMENT OF OCEANOGRAPHY

The Johns Hopkins University offers a broad program of advanced study and research in physical, chemical, biological, and geological oceanography. Facilities of the Department and the affiliated Chesapeake Bay Institute include modern laboratories, an instrument development laboratory and shop, a darkroom, drafting and data reduction facilities, and a research library, all contained in a new building of 37,000 square feet which was occupied in the fall of 1964. Also included in the new oceanography building are a recirculating filtered sea water system, constant-temperature rooms, cold rooms, an isotope-handling laboratory, and a large, circulating water tunnel for testing and calibrating current measuring devices. The Annapolis field laboratory, where research vessels are docked has an instrument laboratory, chemical preparation room, wood and metal-working shop, and storage and maintenance facilities.

A 106-foot twin-hulled research vessel is now under construction, to augment the present research vessels (68-foot MAURY, 39-foot LYDIA LOUISE II, 45-foot DYEBAR and several smaller craft).

Instructional Staff:

DONALD W. PRITCHARD, Ph.D., Professor, Physical Oceanography. Chairman of the Department and Director of Chesapeake Bay Institute
RAYMOND B. MONTGOMERY, Sc.D., Professor, Physical Oceanography
ROBERT N. GINSBURG, Ph.D., Professor, Geological Oceanography
JAMES H. CARPENTER, Ph.D., Assistant Professor, Chemical Oceanography
BLAIR KINSMAN, Ph.D., Associate Professor, Physical Oceanography
W. ROWLAND TAYLOR, Ph.D., Assistant Professor, Biological Oceanography

Degrees Offered:

Master of Arts in Oceanography
Doctor of Philosophy in Oceanography

Courses Offered:

(Only two for undergraduates: 300-level.) Courses 303, 601-602, 616 and 624 are offered in alternate years with 603, 605-606, and 626. The latter are available in 1967-68.

605-606 WAVES AND TIDES
Kinsman

Theory of surface and internal waves; wave forecasting; transformation of waves in shallow water. Tide theory; analysis and prediction of tides and tidal currents.

626 ESTUARINE OCEANOGRAPHY
Pritchard

Physical and chemical properties of estuarine waters, including the kinematics and dynamics of motion. Classification of estuaries by geomorphological and oceanographic parameters. Prerequisite: Oceanography 603.

628 ADVANCED WIND WAVE THEORY
Kinsman

Modern theories of wind wave generation, dissipation and energy transfer on the ocean surface. Prerequisite: Oceanography 605-606 and permission of the instructor.

630 OCEANIC TURBULENCE
Kinsman

Aspects of turbulence applicable to oceans and estuaries.

Chemical Oceanography

624 CHEMISTRY OF SEA WATER
Carpenter

The composition of sea water; the carbon dioxide system; nutrients; laboratory work dealing with the chemical methods of analysis in routine use in oceanography; assembly and correlation of chemical data.

625 ADVANCED CHEMICAL OCEANOGRAPHY
Carpenter

Detailed examination of the chemical and physico-chemical aspects of nutrient systems, the interaction between the bottom and overlying water, and of minor constituents. Review of modern analytical methods with limited laboratory work.

General

301 INTRODUCTION TO OCEANOGRAPHY
Staff

A broad description of the marine environment including characteristics of sea water and theories of ocean currents. An elementary presentation especially for third and fourth year undergraduate students in science and engineering; students who are not majoring in science or engineering may take the course only with special permission of the instructor; not applicable toward a minor in oceanography for the Ph.D., degree.

611-612 SEMINAR IN OCEANOGRAPHY
Staff

Required of all students in the Department.

615 RESEARCH PROBLEMS IN OCEANOGRAPHY
Staff

Independent research for the Ph.D. dissertation. Open to candidates for the Ph.D. degree.

Physical Oceanography

601-602 PHYSICAL OCEANOGRAPHY
Montgomery

Both geographic and hydrodynamic aspects of oceanography are stressed. Topics: relief of the ocean floor; physical properties of sea water; heat and light; observed distributions of temperature, salinity and currents; scalar and vector fields; kinematics; hydrostatics; momentum dynamics; vorticity dynamics; viscosity; Ekman's studies of currents; eddy flux; map projections. Practice is provided in analysis of oceanographic data.

603 ADVANCED THEORETICAL OCEANOGRAPHY
Pritchard

A unified theoretical treatment of the basic hydrodynamic principles as applied to the oceans. The problems of averaging to obtain time mean and spatial mean equations are stressed. A review of current literature on the theoretical aspects of physical and meteorological oceanography is included. Prerequisite: Oceanography 601-602.

Biological Oceanography

303 MARINE ECOLOGY
Taylor

General survey of the populations in marine and estuarine waters. The relationships of physical, chemical and biological factors of the environment to these organisms are discussed. Limited field work included. Permission of instructor required for undergraduate students.

616 BIOLOGICAL OCEANOGRAPHY
Taylor

Consideration of the sea and estuaries as biological environments. Emphasis is placed on marine microbiology, especially phytoplankton and zooplankton. Selected topics in algal physiology and nutrition, biochemistry of photosynthesis, primary productivity in marine waters, and bottom communities, and their relation to the plankton are discussed. The course is designed for students intending to pursue advanced studies in the biological or chemical phases of oceanography.

620 ADVANCED BIOLOGICAL OCEANOGRAPHY
Taylor

Directed reading and discussion of selected topics from current literature.

623 MARINE MICROBIOLOGY
Taylor

Studies of marine and estuarine microorganisms including bacteria, fungi, and unicellular algae such as dinoflagellates and diatoms. Included are discussions of the morphology, taxonomy and certain aspects of physiology, biochemistry, nutrition and bioluminescence of these organisms. Laboratory and field work emphasize isolation and culturing techniques that are unique to the study of marine microorganisms.

### Geological Oceanography

614 MARINE GEOLOGY
Ginsburg

The topography, structure, and history of the ocean basins; origin, deposition and distribution of sediments; interactions between sediments, water and organisms.

8.678 CARBONATES
Ginsburg

The origin and deposition of recent carbonate sediments; diagenesis and the environment and stratigraphy of ancient carbonates.

A wide variety of pertinent courses is available in other departments, including meteorology, fluid mechanics, mechanics of perfect fluids, mechanics of viscous fluids, turbulence mechanics of gravity waves, and geophysical fluid mechanics, all in the Department of Mechanics; limnology and properties and behavior of water, in the Department of Sanitary Engineering and Water Resources; and geochemistry in the Department of Geology.

Person to be contacted for further information:

The Chairman
Department of Oceanography
The Johns Hopkins University
Oceanography Building
Baltimore, Maryland 21218

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## HARVARD UNIVERSITY
Cambridge, Massachusetts 02138

The University considers that specialization in marine science should be undertaken within one of the classical scientific disciplines such as biology, geology, physics, or chemistry. There is no separate department offering work toward a degree in oceanography. The Committee on Oceanography will assist students who wish to prepare themselves for work in this special field, and will help them arrange joint programs of study when that is desired.

Instructional Staff:

FRANCIS BIRCH, Ph.D., Professor of Geology
GEORGE F. CARRIER, Ph.D., Professor of Mechanical Engineering
GEORGE L. CLARKE, Ph.D., Professor of Biology
WILLIAM J. CLENCH, Ph.D., Curator of Mollusks
HOWARD B. FELL, Ph.D., Curator of Invertebrate Zoology
RICHARD M. GOODY, Ph.D , Professor of Dynamic Meteorology
JOHAN A. HELLEBUST, Ph.D., Assistant Professor of Marine Biology
FREDERICK V. HUNT, Ph.D., Professor of Physics and Applied Physics
BOSTWICK H. KETCHUM, Ph.D., Lecturer on Biological Oceanography
GILES W. MEAD, Ph.D., Curator of Fishes
ROGER REVELLE, Ph.D., Professor of Population Studies
ALLAN R. ROBINSON, Ph.D., Associate Professor of Geophysical Fluid Dynamics
RAYMOND SIEVER, Ph.D , Professor of Geology
JOHN H. WELSH, Ph.D., Professor of Zoology
EDGAR B. WILSON, JR., Ph.D., Professor of Chemistry

Degrees Offered:

None in oceanography, but the A.B., A.M., and Ph.D. may be obtained in applied physics, applied mathematics, biology, chemistry, geology, geophysics, or physics.

Courses Offered:

The curricula leading to each of these degrees can contain a substantial amount of attention to oceanographic topics.

### Biology

### Undergraduate Courses

121 INVERTEBRATE ZOOLOGY
Fell

The classification, morphology, development, physiology and importance to man of the major groups of invertebrates.

130 BIOLOGY OF FISHES
Mead

The classification, structure, and natural history of fishes.

143 PRINCIPLES OF ECOLOGY
Clarke

The basic interrelations of plants and animals with the physical and biological factors of the environment. The fundamental concepts of environmental biology. The control of growth, distribution, reproduction, and behavior; development and organization of populations; energy flow and dynamic balance in communities; and productivity of natural areas and biological resources.

146 PHYSIOLOGY AND ECOLOGY OF ALGAE
Hellebust

This course deals with biochemical and physiological aspects of growth and metabolism of algae and with the ecological role of algae in nature. Marine algae will be emphasized, particularly in the laboratory work.

Graduate Courses

243 PROBLEMS IN OCEANOGRAPHY
Clarke

Fundamental ecological relations of the aquatic environment with special consideration of problems of most recent interest in biological oceanography.

245 BIOLOGICAL OCEANOGRAPHY
Ketchum

The major problems in the development, seasonal changes, and variations of populations of aquatic organisms. Recent developments in aquatic biology will be emphasized and will include such subjects as photosynthetic production and its relationship to environmental conditions, the transfer of energy and elements through the food web, the biologically controlled distribution of elements in the sea, estuarine and coastal circulation in relation to the distribution of populations, the uses of radioisotopes for study of oceanographic problems and biological effects of the contamination of the sea with radioisotopes.

333 MALACOLOGY
Clench

334 INVERTEBRATE ZOOLOGY
Fell

335 ICHTHYOLOGY Mead

343 ECOLOGY AND OCEANOGRAPHY
Clarke

345 GRADUATE RESEARCH IN BIOLOGICAL OCEANOGRAPHY
Ketchum

362 INVERTEBRATE PHYSIOLOGY
Welsh

Geology

Undergraduate

111 STRUCTURAL GEOLOGY

157 SEDIMENTOLOGY

151 PALEONTOLOGY

136 PHYSICAL OCEANOGRAPHY

Graduate

211 ADVANCED STRUCTURAL GEOLOGY

252 SEDIMENTOLOGY AND PETROLOGY

322 RESEARCH IN PHYSICAL OCEANOGRAPHY

353 RESEARCH IN SEDIMENTOLOGY AND PETROLOGY

Meteorology and Oceanography

Undergraduate

101 INTRODUCTION TO THE PHYSICS OF THE ATMOSPHERE AND THE OCEAN
Goody, Robinson

Graduate

201 PHYSICS OF ATMOSPHERES AND OCEANS I - DYNAMICS
Robinson

203 PHYSICS OF ATMOSPHERES AND OCEANS II - ENERGY TRANSFER
Goody

212 SPECIAL TOPICS IN GEOPHYSICAL FLUID DYNAMICS
Staff

216 PHYSICAL OCEANOGRAPHY
Robinson

302, 303 RESEARCH IN OCEANOGRAPHY

Person to be contacted for further information·

Chairman
Committee on Oceanography
Faculty of Arts and Sciences
Harvard University
Cambridge, Massachusetts 02138

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## MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, Massachusetts 02139

The Massachusetts Institute of Technology and the Woods Hole Oceanographic Institution have worked out a joint program in oceanography which is expected to lead to jointly-awarded degrees of Doctor of Philosophy and Doctor of Science in Oceanography. Both Institutions have applied for changes in their charters in order to permit the granting of these joint degrees. At M.I.T., the Department of Geology and Geophysics and the Department of Meteorology cooperate closely in this program.

Under this joint program a student would normally spend his first one or two graduate years at M.I.T. and would then undertake his thesis research either at Woods Hole Oceanographic Institution or at M.I.T. depending on his interests and the location of the appropriate facilities. The Woods Hole Oceanographic Institution operates a fleet of research vessels, has extensive laboratory facilities and an outstanding research staff. Extensive resources for advanced study and research in oceanography are available at M.I.T. The Departments of Meteorology and of Geology and Geophysics offer instruction and research opportunities in physical oceanography, chemical oceanography, marine geophysics, and submarine geology. Many other M.I.T. departments offer subjects in the marine sciences or in areas that are basic to oceanography. A modest marine facility is maintained on Boston Harbor consisting of dock space, staging area, a laboratory and a small research boat. These facilities are a useful supplement to the more extensive resources at Woods Hole by providing a ready access to the local oceanic areas for students while they are in residence at M.I.T.

Instructional Staff:

Department of Geology and Geophysics

FRANK PRESS, Ph.D., Department Head and Professor, Geophysics
SHAWN BIEHLER, Ph.D., Assistant Professor, Geophysics
DAYTON E. CARRITT, Ph.D. Professor, Chemical Oceanography
JOHN B. HERSEY*, Ph.D., Professor, Oceanography (on leave 1967-1968)
JOHN W. KANWISHER*, Ph.D., Associate Professor, Oceanography
CLAES ROOTH*, Ph.D., Associate Professor, Physical Oceanography
M. GENE SIMMONS, Ph.D , Professor, Geophysics
WILLIAM S. von ARX, Ph.D., Professor, Physical Oceanography
T. FERRIS WEBSTER*, Ph.D., Assistant Professor, Physical Oceanography
CARL I. WUNSCH, Ph.D., Lecturer, Physical Oceanography

Department of Meteorology

HENRY G. HOUGHTON, Sc.D., Department Head and Professor, Meteorology
JULE G. CHARNEY, Ph.D., Professor, Meteorology
DELBAR P. KEILY, S.B., Associate Professor, Meteorology
ERIK L. MOLLO-CHRISTENSEN, Sc.D., Professor, Meteorology
NORMAN A. PHILLIPS, Ph.D., Professor, Meteorology
VICTOR P. STARR, Ph.D., Professor, Meteorology
HENRY M. STOMMEL, Ph.D., Professor, Oceanography

Degrees Offered:

Master of Science in Oceanography
Doctor of Philosophy in Oceanography
Doctor of Science in Oceanography

Students may specialize in any of the following fields: Marine Geophysics, Physical Oceanography, Chemical Oceanography, Marine Geochemistry.

Courses Offered:

Undergraduate Courses

12.811 PHYSICAL OCEANOGRAPHY
von Arx

Introduction to the physical processes and properties of the oceans; their structure, circulations and relationships to the atmosphere and solid earth.

19.83 PHYSICAL OCEANOGRAPHY
Houghton

Structure and physical properties of the oceans. Methods of measurement and an outline of the observational information. Dynamics of oceanic current systems. Wind currents, waves and tides.

Graduate Courses

12.901-12.909 SPECIAL PROBLEMS IN OCEANOGRAPHY (A)
Staff

For graduate students desiring to perform special investigations, special laboratory work or special field work in oceanography.

12.91 RESEARCH IN PHYSICAL OCEANOGRAPHY (A)
von Arx

For graduate students pursuing a special investigation of some physical aspect of the oceans.

12.912 SEMINAR IN PHYSICAL OCEANOGRAPHY (A)
von Arx

Reading and discussion of classical and contemporary books and papers related to the marine aspects of earth science. Varying content to meet special needs and interests of participants.

12.913 MARINE GEODESY (A)
von Arx

Concepts of classical and modern geodesy considered in relation to physical oceanographic problems; the definition of the geoid at sea by astro-geodetic, gravimetric and satellite techniques; the relief of the physical sea surface with reference to the geoid.

12.92 RESEARCH IN CHEMICAL OCEANOGRAPHY (A)
Carritt

Supervised research on a problem in chemical oceanography.

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* Full time Woods Hole Oceanographic Institution staff, part time M.I.T. staff.

12.921 CHEMICAL OCEANOGRAPHY I (A)
Carritt

Study of the chemical systems in the oceans; the composition of sea water; the density-chlorinity-salinity relationships; the carbon dioxide system; the nutrient systems; dissolved gases; the routes and rates of material and energy transfer between hydrosphere, biosphere, and geosphere. Discussion of the methods of measurement of the dissolved substances in sea water.

12.922 CHEMICAL OCEANOGRAPHY II (A)
Carritt

Readings in the contemporary literature and discussion of several topics chosen to fit the backgrounds, fields of study, and interests of the participants. Topics in which chemical data are used in the interpretation of natural processes in the sea, such as carbon 14 dating in marine sediments in sea water; exchange of carbon dioxide (and other gases) across the sea surface; rates of physical, biological and geological processes in the oceans as inferred from chemical data; discussion of chemical species in natural fresh and salt waters.

12.93 WAVES AND TIDES
Wunsch

Aspects of tide and wave motion in the sea and atmosphere. Derivation of the tide producing forces. Hydrostatic and non-hydrostatic approximations. Oceanic wave motions as examples of geophysical time series; stochastic surfaces, prediction, spectra and bi-spectra, filtering, etc. Content will vary from year to year.

12.991-12.999 SEMINAR IN OCEANOGRAPHY (A)
Staff

Topics in marine geophysics, physical, dynamical and chemical oceanography, Content varying from term to term.

19.22 AIR AND SEA INSTRUMENTS (A)
Keily

Lectures and laboratory exercises on the design and response characteristics of typical instruments and instrument systems used for measurements in the atmosphere, in the oceans, and in the sea-air interfacial region.

19.24 FLUID DYNAMICS LABORATORY
Mollo-Christensen

Experiments on processes and phenomena in geophysical fluid mechanics. Design of experiments, similarity, experimental methods, data processing. Laboratory work involving quantitative observation of hydrodynamic instability, transport processes and turbulence.

19.64 DYNAMIC METEOROLOGY II (A)
Starr

Large-scale atmospheric motions. Examination of recent theories of the general circulation. Research in the application of fluid mechanics to meteorology and oceanography.

19.67 PLANETARY FLUID DYNAMICS (A)
Charney

Discussion of fluid dynamical problems on the planetary scale with examples drawn from the atmosphere, the oceans and the interior of the earth. Convectively driven circulations in rotating systems and high-speed computational methods for the solution of the governing equations.

19.84 DYNAMIC OCEANOGRAPHY (A)
Starr, Phillips

Elementary theory of wave motion in the ocean, including tidal phenomena. Restatement of various principles of fluid mechanics with special emphasis on the effects of currents.

19.86 OCEANIC CIRCULATIONS (A)
Stommel

Large-scale circulation of the oceans as revealed by the analysis of hydrographic data, direct current measurements and the distribution of properties and tracers. Emphasis on the relation between observations and recent theories of the main thermocline and the associated thermohaline circulation.

19.87 SEMINAR IN PHYSICAL OCEANOGRAPHY (A)
Stommel

Readings and discussions of current research topics in physical oceanography. Emphasis on circulations of the ocean with choice of topics from most interesting subjects in current literature.

19.89 SPECIAL PROBLEMS IN OCEANOGRAPHY (A)
Staff

Reading, consultation, and original investigation on oceanographic problems.

19.97 SPECIAL SUBJECT IN OCEANOGRAPHY (A)
Staff

Organized lecture or laboratory subject on some aspect of oceanography not normally covered in the regularly scheduled subjects.

Persons to be contacted for further information:

Professor Frank Press, Head
Department of Geology and Geophysics
Room 54-912
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Professor H. G. Houghton, Head
Department of Meteorology
Room 54-1712
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

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## NORTHEASTERN UNIVERSITY
Boston, Massachusetts 02115

Northeastern University is developing a marine research institute on a 20-acre former NIKE missile site on the shoreline at Nahant, Massachusetts. The marine facility is being utilized by faculty and graduate students for research in areas of biological oceanography, earth science and ocean engineering.

Instructional Staff:

Northeastern University Marine Institute

NATHAN W. RISER, Ph.D., Director

Department of Natural Science

J. ROSSON OVERCASH, A.M.T., Chairman
BERNARD L. GORDON, M.Sc., Assistant Professor

Degrees Offered:

No degrees are offered in oceanography at present, but education undergraduates can major in earth science and all students may receive oceanographic background on cooperative jobs at marine-oriented corporations and firms. Advanced degrees incorporating marine research thesis problems are developed in biology, chemistry, and engineering.

Courses Offered:

Department of Natural Science

Undergraduate

16.131 OCEANOGRAPHY I
Gordon

An introduction to the nature of the ocean basins and the physical and chemical properties of sea water. Special attention is given to the development of ocean currents and the important effects these currents have on the land masses of the world.

16.132 OCEANOGRAPHY II
Gordon

Emphasis is placed on the habitat zones and organisms of the sea. Phytoplankton, zooplankton, and nekton are discussed. Attention is given to the growing economic importance of marine resources for the expanding world populations.

NOTE: In both courses, field trips are taken to the Woods Hole Oceanographic Institution, Boston Fish Pier, and available research vessels.

Biology Department

Graduate

18.830 MARINE ALGAE

Systematics, life histories, and ecology of marine algae, with emphasis on the flora of the Gulf of Maine. (Offered Summer Quarter, at Nahant, Mass.)

18.905 MARINE MICROBIOLOGY

Morphological, physiological, and ecological factors concerning marine micro-organisms. Taxonomic problems, microbial association, and general methodological approaches to the study of marine micro-organisms.

University College (Part-time, Adult Education Degree-Oriented Programs)

16.531 OCEANOGRAPHY I

An introduction to the geology of the ocean basins and the physical and chemical properties of sea water. The development of ocean currents and their effect on the land masses of the world.

16.532 OCEANOGRAPHY II

The habitat zones and organisms of the sea. Phytoplankton, zooplankton and nekton are discussed. The growing economic importance of marine resources for the expanding world population.

16.533 MARINE GEOLOGY

Physiography and structure of ocean basins. Marine geological processes and features including sedimentation, erosion, shorelines and bottom topography. Methods and techniques of marine geological exploration.

16.534 FISHERIES OCEANOGRAPHY I - SURVEY OF COMMERCIALLY IMPORTANT MARINE ORGANISMS

An introduction to life histories, and distribution of commercially important seaweed, shellfish, and fishes. Population dynamics and fishery potential of the world's oceans are considered. An analysis of fishery stocks and sea farming is made.

16.535 FISHERIES OCEANOGRAPHY II - COMMERCIAL FISHING METHODS, TECHNIQUES AND EQUIPMENT

Methods of harvesting the seas are studied from past to present. An analysis of the various fisheries of the Atlantic Ocean with their equipment is carried out. Latest techniques of electric and photic fish capture are discussed.

**16.536 FISHERIES OCEANOGRAPHY III - COMMERCIAL FISHERY PRODUCTS AND THEIR EXPLOITATION**

A study of the commercial products and applications of marine organisms such as a seaweed, fish, shellfish is made. Particular emphasis is placed on the marine products of commerce from the New England area. Chemical industrial and dietary applications of marine products are studied.

Person to be contacted for further information:

Professor Bernard L. Gordon
Department of Natural Science
Northeastern University
Boston, Massachusetts 02115

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## SOUTHEASTERN MASSACHUSETTS TECHNOLOGICAL INSTITUTE

North Dartmouth, Massachusetts 02747

The main campus of the Southeastern Massachusetts Technological Institute is located on a 730 acre tract in North Dartmouth. Temporary facilities at the seaport towns of New Bedford and Fall River house research laboratories which are scheduled to be closed as new laboratory facilities are constructed on the North Dartmouth campus. A new science-engineering laboratory building is scheduled for completion early in 1968. A research building, which will house more than 3,000 square feet of marine and aquatic laboratories, is scheduled for completion in 1969.

A 5,000 square foot marine laboratory and wharf facilities are located at nearby Westport Point. The Institute owns a 66 foot oceanographic vessel, the former Environmental Science Services Administration ship, the WAINWRIGHT, in addition to small craft which are available for teaching and research on Buzzards Bay and the estuaries.

Instructional Staff:

LENINE M. GONSALVES, M.S.E.E., Professor of Electrical Engineering
JAMES G. HOFF, Ph.D., Assistant Professor of Biology
AGNAR INGOLFSSON, Ph.D., Assistant Professor of Biology
DAVID A. McGILL, Ph.D., Assistant Professor of Biology
SANFORD A. MOSS, Ph.D., Assistant Professor of Biology
JACK A. PEARY, Ph.D., Assistant Professor of Biology

Degrees Offered:

Oceanology Option in Electrical Engineering, B.S.
Marine Science Option in Biology, B.S.

Both of the above undergraduate programs are variations within established baccalaureate degrees in biology and engineering. During the junior and senior years, students electing these options, are required to select prescribed courses in ocean engineering, marine biology and oceanography.

A masters degree program in marine biology has been authorized and is scheduled to be implemented in 1969.

Courses Offered:

Ocean Engineering

**PHY 544 PHYSICAL OCEANOGRAPHY**

Marine Biology

**BIO 315 THE BIOLOGY OF ALGAE**

A survey of the principal taxa of marine, estuarine and fresh water algae. Emphasis will be placed on analysis of structure and identification of the more common species of algae of northeastern U.S. and adjacent waters. Extended field trips, some of which will be held on weekends and/or holidays, are an integral part of this course. Prerequisite: Consent of instructor.

**BIO 317 THE BIOLOGY OF INVERTEBRATE ANIMALS**

An intensive survey of the taxonomy, morphology and function of the major invertebrate phyla. Field studies will emphasize the ecology and adaptations of marine invertebrates of the North Atlantic coast. Extended field trips, some of which will be held on weekends and/or holidays are an integral part of this course. Lecture 3 hours, laboratory 3 hours. Prerequisite: Consent of instructor.

**BIO 413 THE BIOLOGY OF FISHES**

The classification, life histories and ecology of fishes with emphasis on the study of representative species of the northeastern states and their coastal waters. Extended field trips, some of which will be held on weekends and/or holidays, are an integral part of this course. Lecture 2 hours, laboratory 5 hours. Prerequisite: Consent of instructor.

**BIO 414 COMPARATIVE PHYSIOLOGY**

Adaptions in physiological mechanisms as illustrated by selected vertebrate and invertebrate species. Regulatory mechanisms, muscle action, gas exchange, nerve action, membranes, circulation and metabolism. Lecture 3 hours, laboratory 3 hours. Prerequisite: Consent of instructor.

415 LIMNOLOGY

The physics and chemistry of lakes, ponds, rivers and estuaries. Emphasis on the measurement and analysis of chemical and physical characteristics of water masses. The effects of physical and chemical factors on the distribution of organisms. Extended field trips, some of which will be held on weekends and/or holidays, are an integral part of this course. Lecture 2 hours, laboratory 5 hours. Prerequisite: Consent of instructor.

440-441 RESEARCH PROJECTS

Investigations are carried out under the supervision of a faculty member. Student must satisfy the supervising professor concerning the student's ability to carry on independent research. Prerequisite: Consent of instructor.

544 GENERAL OCEANOGRAPHY

A study of the physical, chemical and biological factors characterizing the marine environment and a consideration of factors controlling plant and animal populations. Methods of sampling and analysis will be surveyed. Lecture 4 hours. Prerequisite: Senior or graduate standing in biology, chemistry, physics or engineering and consent of instructor.

rson to be contacted for further information:

Dr. John J. Reardon
Chairman of Biology Department
Southeastern Massachusetts Technological
Institute
North Dartmouth, Massachusetts 02747

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## UNIVERSITY OF MICHIGAN
Ann Arbor, Michigan 48104

### EOROLOGY AND OCEANOGRAPHY

The Department of Meteorology and
eanography includes laboratories for at-
spheric turbulence and scintillation
search and studies of cloud and precipita-
on physics, a computer laboratory containing
hybrid analog-digital computer, meteorological
strumentation, and facilities for general,
ysical and chemical oceanography and sub-
rine geology.

A fleet of three fully equipped research
ssels maintained in the Great Lakes by the
eat Lakes Research Division of the Univer-
ty's Institute of Science and Technology is
ilable for staff and student field studies
oceanography. Though the Great Lakes
search Division is a research facility not
ectly involved in teaching, it has a firm
icy of assisting in the educational program
rough the research of faculty and students.

Recent research activities of faculty and students in oceanography include: air-sea interface phenomena, circulation and diffusion processes, sediments and sedimentation processes, air-mass modification, water quality modification by man's wastes, geological structure of the Great Lakes basins, Great Lakes climatology, ecology of plankton and benthic organisms, as well as waves and wave prediction.

Instructional Staff:

JOHN C. AYERS, Ph.D., Professor of Oceanography
ALAN L. COLE, Ph.D., Lecturer
ALBERT NELSON DINGLE, Sc.D., Professor of Meteorology
EDWARD S. EPSTEIN, Ph.D., Associate Professor of Meteorology
GERALD C. GILL, M.A., Professor of Meteorology
E. WENDELL HEWSON, Ph.D., Professor of Meteorology
JACK L. HOUGH, Ph.D., Professor of Oceanography
STANLEY J. JACOBS, Ph.D., Assistant Professor of Oceanography
DONALD J. PORTMAN, Ph.D., Professor of Meteorology
AKSEL C. WIIN-NIELSEN, Fil.Dr., Professor of Meteorology and Oceanography
JOHN W. WINCHESTER, Ph.D., Associate Professor of Meteorology and Oceanography

Degrees Offered:

B.S., M.S., and Ph.D., in Oceanography

Courses Offered:

Undergraduate

304 INTRODUCTION TO ATMOSPHERIC AND OCEANIC SCIENCES I
Staff

The various aspects of meteorology and oceanography. Emphasis is placed on the geophysical and geochemical origins, composition, structure and motions of the atmosphere and oceans.

305 INTRODUCTION TO ATMOSPHERIC AND OCEANIC SCIENCES II
Staff

A continuation of M&O 304, with emphasis on the description and physical basis of geophysical fluid wave motions, and other physical and biological processes, introducing the student to various aspects of aeronomy, meteorology and oceanography.

306 LABORATORY IN GEOPHYSICAL DATA I
Cole

An introduction to atmospheric and oceanic data, and their practical treatment; exercises in the analysis of geophysical data in space and time, methods of observation of different elements.

307 LABORATORY IN GEOPHYSICAL DATA II
Cole

Analysis of meteorological and oceanographic data, measurements of currents and winds, vertical distributions of different elements in the oceans and atmospheres, data analysis in aeronomy.

350 OCEAN ENGINEERING (Engineering Mechanics 324)
Staff

A descriptive course intended to familiarize naval architecture students with relevant aspects of oceanography and oceanography students with basic naval architecture, and to introduce students in both disciplines to the evolving field of ocean engineering. Pertinent physical, chemical, biological and geological properties of the oceans, basic naval architecture and engineering analysis of research platforms and vehicles, oceanographic instrumentation, physical oceanography, underwater acoustics, and other selected topics.

351 GEOPHYSICAL FLUID DYNAMICS
Jacobs

Dynamics and thermodynamics of the oceans and the atmosphere. Equations of motion for a rotating system; thermodynamics; kinematic principles; vorticity; geostrophic flow.

417 GEOLOGY OF THE GREAT LAKES
Hough

Geologic history of the late-glacial and post-glacial Great Lakes of North America, with emphasis on evaluation of evidence. Related topics such as bedrock setting, engineering problems, and physical environment of sedimentation.

442 OCEANIC DYNAMICS I
Jacobs

Wave motions; group velocity and dispersion. Gravity waves, wave statistics and prediction methods; long period waves; the tides. Steady state circulation, including theories of boundary currents and the thermocline.

443 LIMNOLOGY AND OCEANOGRAPHY (Zoo. 443)
Staff

Lectures on the environmental conditions which affect the biotic assemblages in the world's aquatic habitats.

449 MARINE GEOLOGY
Hough

Topography, geomorphology, sediments, processes and environments of the oceans; characteristics of oceanic segments of the earth's crust; theories of structural development.

478 MARINE CHEMISTRY
Winchester

Chemical properties of sea water and equilibria with carbonate, silicate, and other sedimentary materials and with the atmosphere. Discussion of global distribution of marine sediments, formation of manganese nodules, determination of paleotemperatures by oxygen isotopes, and the long-term history of sea water.

531 MARINE ECOLOGY
Ayers

Interactions of biological, chemical, geological, and physical factors in the marine environment. Designed to show and analyze the complex interrelationships occurring in the aquatic environment, especially as these are reflected by the biological economy.

542 OCEANIC DYNAMICS II
Jacobs

Circulation in the world ocean; interaction of the oceans and atmosphere; boundary currents, the thermocline, equatorial currents; the thermohaline circulation.

675, 676 CURRENT PROBLEMS IN LIMNOLOGY AND OCEANOGRAPHY
Staff

Discussion of current concepts and problems varying in content and designed to put the student in touch with recent advances and with areas of uncertainty presently under investigation. Designed to familiarize the student with dynamics, biology, sedimentation, and other major areas of the field. Student expected to register more than one year.

678 ATMOSPHERIC AND MARINE CHEMISTRY
Winchester

Intensive study of areas of current research interest stressing chemical processes occurring at interface between gas, liquid, and solid.

701 SPECIAL PROBLEMS IN METEOROLOGY AND OCEANOGRAPHY

Supervised analysis of selected problems in various areas of meteorology and oceanography.

Person to be contacted for further information:

Dr. A. Wiin-Nielsen
Chairman
Department of Meteorology and Oceanography
2038 East Engineering Building
Ann Arbor, Michigan 48104

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## UNIVERSITY OF NEW HAMPSHIRE

Durham, New Hampshire 03824

Marine-oriented courses and research at the University of New Hampshire are divided into two categories: ocean-oriented engineering* and marine science. These activities are conducted, and degrees granted, within the framework of the fundamental engineering and scientific disciplines involving the Departments of Civil, Chemical, Electrical and Mechanical Engineering and the science Departments of Botany, Biochemistry, Microbiology, Zoology, Geology and Physics.

### Marine Science

### The New Hampshire Estuarine Laboratory

The Laboratory, constructed in 1967, is located at the junction of Little and Great Bays, approximately five miles from the University at Durham and fifteen miles from the ocean. The Laboratory occupies about 8,400 square feet and contains modern facilities for the Departments of Botany, Biochemistry, Microbiology and Zoology including a large circulating seawater system and a shop.

The University has small skiffs and motored boats for collecting in the estuary. Open ocean work is carried out through the auspices of the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts and the Narragansett Marine Station, University of Rhode Island, Kingston, Rhode Island.

Instructional Staff:

- A. C. BORROR, Ph.D., Associate Professor of Zoology
- W. L. BULLOCK, Ph.D., Professor of Zoology
- W. R. CHESBRO, Ph.D., Associate Professor of Microbiology
- R. A. CROKER, Ph.D., Assistant Professor of Zoology
- M. IKAWA, Ph.D., Professor of Biochemistry
- G. E. JONES, Ph.D., Director, New Hampshire Estuarine Laboratory, Professor of Microbiology
- G. KLIPPENSTEIN, Ph.D., Assistant Professor of Biochemistry
- M. E. LAVOIE, Ph.D., Associate Professor of Zoology
- A. MATHIESON, Ph.D., Assistant Professor of Botany
- T. G. METCALF, Ph.D., Professor of Microbiology
- L. J. MILNE, Ph.D., Professor of Zoology
- J. J. SASNER, Ph.D., Assistant Professor of Zoology
- P. J. SAWYER, Ph.D., Associate Professor of Zoology
- L. W. SLANETZ, Ph.D., Professor of Microbiology
- B. C. STAUGAARD, Ph.D., Assistant Professor of Zoology
- E. F. SWAN, Ph.D., Professor of Zoology
- P. A. WRIGHT, Ph.D., Professor of Zoology

Degrees Offered:

Master of Arts in Life Science Departments
Doctor of Philosophy in Life Science Departments

Courses Offered:

### Available to undergraduate and graduate students

Zoology 701 PRINCIPLES OF ECOLOGY
Zoology Staff

The interrelationships of plants and animals with both their living and non-living environments. Energy relationships, limiting factors, community organization, succession and biogeography.

Microbiology 708 MARINE MICROBIOLOGY
Jones

Characterization of microbes in the sea as to taxonomy, physiology, ecology, and transformation of carbon, nitrogen, sulfur, and phosphorus; methods of sampling and enumeration; biogeochemistry; properties of sea water and the marine environment.

Zoology 711 NATURAL HISTORY OF COLD BLOODED VERTEBRATES
Sawyer

The various classes of poikilothermic vertebrates, their habits, habitats, and life histories, with special reference to those occurring in eastern North America.

Zoology 715 NATURAL HISTORY OF MARINE INVERTEBRATES
Moore

A field and laboratory course aimed at acquainting the student with the inshore marine invertebrate metazoan animals of northern New England. Emphasis is on identification, classification, habit preferences, and behavior of these animals. Field work (collection and observation) constitute a major part of the course and the student must be prepared to assume some travel expense.

Botany 759 INTRODUCTION TO BIOLOGICAL OCEANOGRAPHY AND MARINE ECOLOGY
Mathieson

Introduction to the distribution, abundance and growth of marine plants in relation to their chemical, physical and biological environments.

### Available to graduate students

Zoology 803 MARINE ECOLOGY
Croker

The marine environment and its biota, with emphasis on intertidal and estuarine habitats. Laboratory and field work will stress inquiry, and the application of ecological, physiological, behaviorial biometrical, systematic, and chemical techniques to local problems. Field trips may be scheduled for early morning, late afternoon, or weekends. Travel will be at student's expense and should not exceed $30 for the course.

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* A description of the University's ocean-oriented engineering curriculum can be found in Chapter 2.

Zoology 820 821 INVERTEBRATE ZOOLOGY
Swan, Moore

The morphology, phylogeny and natural history of the major invertebrate groups.

Zoology 822 PROTOZOOLOGY
Borror

The general biology of protozoa with particular emphasis on morphology, natural history, and economic importance.

Zoology 823 THE HOST-PARASITE RELATIONSHIP
Bullock

Examination of the interactions of host and parasite, using examples from fish, wildlife, and human parasitology. Particular attention will be given to ways in which host ecology influences parasite populations and the interplay of host and parasite in parasite pathology and immunology.

Zoology 826 COMPARATIVE PHYSIOLOGY
Milne, Sasner

The means whereby animals, both vertebrate and invertebrate, have met the problems of irritability, nutrition, maintenance of a constant internal environment and reproduction.

Zoology 830 INVERTEBRATE EMBRYOLOGY
Staugaard

The developmental patterns as exhibited by the major invertebrate groups. This is essentially a descriptive study based upon lectures, library, and laboratory work with living material.

Botany 880 ADVANCED MARINE PHYCOLOGY
Mathieson

The classification, ecology and life histories of marine algae considered at an advanced level. Subject conduced through seminars, discussions, assigned reading and laboratory work.

## Geology

The Geology Department's teaching and research facilities are located in a newly renovated building at the University's Durham campus. The proximity of Durham to the Great Bay Estuary, the open-ocean coastal areas of New Hampshire and southeastern Maine and to the off-shore Isles of Shoals provides easy access to a variety of situations in which marine geological study and research can be conducted.

Instructional Staff:

- R. E. ANDERSON, Ph.D., Assistant Professor of Geology
- W. A. BOTHNER, Ph.D., Assistant Professor of Geology
- D. H. CHAPMAN, Ph.D., Professor of Geology
- H. E. GAUDETTE, Ph.D., Assistant Professor of Geology
- T. R. MEYERS, M.A., Professor of Geology
- C. J. SCHNEER, Ph.D., Professor of Geology
- G. W. STEWART, M.S., Associate Professor of Geology
- H. TISCHLER, Ph.D., Professor of Geology

Degrees Offered:

Master of Science in Geology

Courses Offered:

### Available to undergraduate students

Geology 501 INTRODUCTION TO OCEANOGRAPHY
Anderson

Descriptive and regional oceanography covering the physical, chemical, biological and geological aspects of the sea.

### Available to undergraduate and graduate students

Geology 741 PRINCIPLES OF GEOCHEMISTRY
Gaudette

The chemical approach to the interpretation of geological processes with emphasis on the principles which control the distribution and migration of elements in geological environments.

Geology 754 SEDIMENTOLOGY
Tischler, Anderson

The properties of sediments and sedimentary rocks, the sedimentary processes and environments, correlation procedures and stratigraphic principles.

Geology 755 MARINE GEOLOGY
Anderson

Course proposed for semester II, 1967-68.

Geology 795 SPECIAL PROBLEMS
Staff

The topics under this heading include geochemistry, geophysics, marine geology, micropaleontology and sedimentation.

### Available to graduate students

Geology 895 SPECIAL PROBLEMS (Advanced Level)
Staff

Subject material similar to that contained in Geology 795.

## Physics

The Physics Department operates the Underwater Shock-Wave Laboratory, a small scale facility consisting of 14' x 5' x 4' deep tank approximately instrumented with transducers and recording equipment. This facility is being used currently for the study of shock-wave propagation and reflection phenomena from various interfaces as well as shock-wave dissipation in various media.

Instructional Staff:

H. H. HALL, Ph.D., Professor of Physics
D. G. CLARK, Ph.D., Associate Professor of Physics

Courses Offered:

Available to graduate students

Physics 899 MASTER'S THESIS IN PHYSICS
Hall

Physics 999 DOCTOR'S THESIS IN PHYSICS
Hall

Office to be contacted for further information:

The Marine Affairs Coordinator
Kingsbury Hall
University of New Hampshire
Durham, New Hampshire 03824

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## COLUMBIA UNIVERSITY
New York, New York 10027

Graduate students in marine sciences at Columbia University normally enroll in the Department of Geology, those in marine biology enroll in the Department of Biological Sciences. There is no separate Department of Oceanography. Students follow a program of study based on the varied courses offered within these departments. They also take courses in other departments at Columbia University, particularly in the Departments of Physics and Chemistry and the School of Engineering. The major research facilities for the marine sciences (along with an extensive oceanographic library and computer facilities) are located at the Lamont Geological Observatory campus of Columbia University in Palisades, New York. At Lamont, research is conducted in physical, chemical, geophysical and biological oceanography as well as solid earth geophysics, geochemistry and meteorology. The graduate student, besides following a curriculum in the basic science related to his field of specialization, participates in the general oceanographic program at Lamont and performs original research. The students have access to the material collected on numerous deep-sea expeditions of Lamont ships; among this data is the largest collection of deep-sea cores in the world. The Lamont Observatory carries out oceanographic work aboard the 202 ft., 734-ton, 3-masted schooner, VEMA, and the 208 ft., 1370-ton AGOR-3, ROBERT D. CONRAD. In addition, polar oceanographic programs are conducted aboard the U.S.N.S. ELTANIN in conjunction with the Office of Antarctic Programs of the National Science Foundation, and the laboratories located on drifting ice in the Arctic Ocean. Columbia University operates a geophysical field station in Bermuda which specializes in the underwater propagation of sound. They conduct field research in the North Atlantic and the Caribbean aboard the vessel, SIR HORACE LAMB.

Instructional Staff:

LEONARD E. ALSOP, Adjunct Associate Professor
ORSON L. ANDERSON, Professor
ALLAN W. H. BE, Senior Research Associate, L.G.O.
WALLACE S. BROECKER, Professor
PAUL BURKHOLDER, Senior Research Associate and Lecturer, L.G.O.
WILLIAM L. DONN, Senior Research Associate (Visiting)
CHARLES L. DRAKE, Associate Professor
W. MAURICE EWING, Director of Lamont Geological Observatory and Professor
G. DONALD GARLICK, Assistant Professor
PAUL GAST, Professor
ARNOLD L. GORDON, Assistant Professor
JAMES D. HAYS, Assistant Professor
BRUCE C. HEEZEN, Associate Professor
JAMES R. HEIRTZLER, Senior Research Associate, L.G.O.
KENNETH L. HUNKINS, Senior Research Associate, L.G.O. and Lecturer
TAKASHI ICHIYE, Senior Research Associate, L.G.O. and Lecturer
JOHN T. KUO, Associate Professor
JOHN E. NAFE, Professor
JACK E. OLIVER, Professor
OSWALD ROELS, Senior Research Associate, L.G.O.
LYNN SYKES, Adjunct Assistant Professor
MANIK TALWANI, Associate Professor
J. LAMAR WORZEL, Associate Director, L.G.O. and Professor

Degrees Offered:

Master of Arts
Doctor of Philosophy

Courses Offered:

Graduate Only

Geology Department

These are the basic courses from which the student can choose. The exact curriculum depends on his field of specialization and is decided upon by the student and his advisor.

*G6881x CHEMICAL EQUILIBRIA IN GEOLOGIC SYSTEMS
Broecker

Principles of elementary thermodynamics applied to geologic problems, including phase transformations in the upper mantle, metamorphic reactions, melting-point depression, and the association of authigenic minerals in sedimentary rocks. Statistical mechanics and its application to isotope equilibria are briefly introduced.

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* x indicates autumn term

**W4928y SUBMARINE GEOLOGY
Ewing, Heezen

A survey course on the geology of the deep sea; topography, crustal structure, sediments and sedimentary processes, and elements of oceanography.

W4941x INTRODUCTION TO GEOPHYSICS
Nafe

The structure of the earth as inferred from geophysical investigations. The principles of geophysical measurement and interpretation, gravity measurement, isostasy, geomagnetism, geothermal measurement, earthquake seismology, seismic refraction and reflection.

G6927x OCEANOGRAPHY
Broecker, Gordon

Physical and chemical oceanography; properties of sea water; water masses of the oceans; ocean circulation; measurement techniques; special topics on chemistry and geochemistry of the oceans.

G6928 ADVANCED SUBMARINE GEOLOGY
Heezen

G6946y ELASTIC WAVES
Nafe, Alsop

An introductory course in the theory of waves in fluids and elastic media, with particular emphasis on geophysical applications. Necessary mathematical techniques are developed as required.

G8928y DYNAMICAL OCEANOGRAPHY
Nafe

Dynamics of oceanic circulation, waves, tides, seiches.

G8943x GENERAL GEOPHYSICS
Ewing, Nafe, Worzel

G9929x or y SEMINAR IN PHYSICAL OCEANOGRAPHY
Hunkins, Ichiye

Critical study of current literature on the dynamics of ocean circulation, including wind-driven and thermohaline currents, oceanic turbulence, wave motion and model experiments.

W4226x EXPERIMENTAL MARINE SEDIMENTOLOGY
Fairbridge

Theory and techniques of modern marine sedimentology especially the chemical processes associated with deposition and diagenesis.

G6223y PRINCIPLES OF SEDIMENTATION
Kay

The processes and agents that form, transport, and deposit sediments and the interpretation of the resulting rocks. Laboratory studies emphasize the principles and methods of analysis and the explanation of characters shown in rock specimens and thin sections.

G6945x GEO-DYNAMICS
Nafe, Alsop

### Physics Department

G4003x LAGRANGIAN MECHANICS

G6019x MATHEMATICAL METHODS IN PHYSICS

G6051x - G6052y ADVANCED LABORATORY WORK

### School of Engineering and Applied Science

E4201x or y PARTIAL DIFFERENTIAL EQUATIONS, I

E4204x or y FUNCTIONS OF A COMPLEX VARIABLE

E4261x BASIC CONTINUUM FLUID MECHANICS

E4262y STATISTICAL THEORY OF TURBULENCE

E6365y HYDRODYNAMICS

E6367x HYDRODYNAMIC STABILITY

### Chemistry Department

G4131x INTRODUCTION TO CHEMICAL PHYSICS

G4133y CHEMICAL AND STATISTICAL THERMODYNAMICS

G4134y RADIOCHEMISTRY

### Department of Biological Sciences

G6071x MARINE MICROBIOLOGY

G6074y BIOLOGY OF PLANKTON

Person to be contacted for further information:

Professor John E. Nafe
Educational Coordinator
Geology Department
Columbia University
New York, New York 10027

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## CORNELL UNIVERSITY
Ithaca, New York 14851

Cornell's long-standing interest in aquatic biology and related sciences comes in part from its location on Cayuga Lake. Lakeside facilities make this large and deep lake available for many kinds of studies. On the Cornell campus facilities available for aquatic studies include not only all the usual

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** y indicates spring term

laboratory facilities, but also specially equipped oceanographic and limnological laboratories, constant temperature rooms, aquarium rooms, and experimental fish rearing facilities. In addition, many of the staff carry on active research in cooperation with various marine laboratories. Since 1966 Cornell has offered a summer course in field marine biology at the Isles of Shoals just off the coast of New Hampshire.

## Division of Biological Sciences

Instructional Staff:

ROBERT S. MORISON, M.D., Director, Division of Biological Sciences
JOHN ANDERSON, Ph.D., Professor of Zoology
JOHN P. BARLOW, Ph.D., Associate Professor of Oceanography
JOHN M. KINGSBURY, Ph.D., Associate Professor of Botany
EDWARD C. RANEY, Ph.D., Professor of Zoology

Degrees Offered:

No undergraduate degrees in marine sciences but the B.S. may be taken with a major sequence in marine ecology. Candidates for the Ph.D. may major or minor in oceanography, vertebrate zoology (ichthyology), botany (phycology), or invertebrate zoology.

Courses Offered:

INVERTEBRATE ZOOLOGY
Anderson

Lectures on selected topics in the development, structure, function, and interrelations of invertebrate animals, with particular attention to phylogenetic aspects. Intensive laboratory work in representative invertebrates, utilizing living or fresh specimens wherever possible. A significant amount of independent work is required of each student, including reports on library research.

ADVANCED INVERTEBRATE ZOOLOGY
Anderson

Lectures and seminars (involving student participation by means of prepared reports) on significant problems in invertebrate zoology; laboratory and field work on selected invertebrate groups.

MARINE ECOLOGY
Barlow

Introduction to biological oceanography: the sea as an environment; physical and chemical characteristics of marine habitats, relation to biogeography; organic production, biochemical cycles and distribution of nonconservative properties; relation of hydrography to fisheries and distribution of populations; oceanographic aspects of pollution problems.

OCEANOGRAPHY
Barlow

Introduction to physical and chemical aspects of the oceans: geography and structure of ocean basins; origin and physical properties of seawater; distribution of salinity and temperature, heat and water budgets, formation of water masses; circulation, waves and tides; shore processes, formation and distribution of sediments; discussion of current problems in oceanography. Laboratory work in organization and analysis of oceanographic observations.

BIOLOGY OF THE ALGAE
Kingsbury

Structure, ecology, physiology, relationships, evolution, and economic uses are presented as appropriate to a detailed understanding of the bluegreen, green, yellowgreen, golden brown, and euglenoid algae. Living material of a large number of genera is provided in laboratory to illustrate lecture topics, to demonstrate characteristics of algae of potential value in research on general biological problems, to provide practice in techniques of isolation and culture, and to develop a working familiarity with the local algal flora. Biologically important characteristics of ponds and streams are brought out in relation to the algae populating them.

BIOLOGY OF THE ALGAE
Kingsbury

A continuation of above course, covering the diatoms, dinoflagellates, brown, and red algae and emphasizing the characteristics of the marine environment.

ICHTHYOLOGY
Raney

Lectures on the biology of fishes including systematics, ecology, life history, behavior, and literature. Laboratory studies of the order, major families, and principal genera, and of systematic procedures. Field studies of the ecology and life history of local species.

## Department of Conservation

Instructional Staff:

DWIGHT A. WEBSTER, Ph.D., Head, Department of Conservation, Professor of Fishery Biology
CLARENCE A. CARLSON, Ph.D., Assistant Professor of Fishery Biology
ALFRED W. EIPPER, Ph.D., Associate Professor of Fishery Biology

Courses Offered:

FISHERY SCIENCE
Webster

Principles and theories involved in dynamics of fish populations. Methods of obtaining and evaluating statistics of growth, population size, mortality, yield, and production, as well as investigational aspects of fishery biology are included.

FISH ECOLOGY
Carlson

Interactions between fishes and their living and non-living environment, and applications of ecological principles to fish population research and management. Competition, predation, parasitism, commensalism, and other biotic interactions involving fishes. Adaptations, behavior, distribution, and life histories of major taxonomic groups. The ecology of young fishes is stressed, and the student is introduced to the literature of fishery biology.

FISHERY RESOURCE MANAGEMENT
Eipper

Principles and problems in the management of freshwater and marine fishery resources, considered in relation to problems of human population and management of other natural resources. Multiple use, evaluation, and allocation of water resources, with particular reference to fisheries. Characteristics of fishery resources of their exploitation. Application of fishery science to the management of fish stocks through maintenance and improvement of habitat, fish population manipulation, and regulation of fishing.

## Department of Geological Sciences

Instructional Staff:

GEORGE A. KIERSCH, Ph.D., Chairman, Department of Geology
ARTHUR L. BLOOM, Ph.D., Associate Professor of Geological Sciences
SHAILER S. PHILBRICK, Ph.D., Professor of Geological Sciences

Degrees Offered:

M.S. or M.A. degree (thesis required). MAST - no thesis. Ph.D. degree with major in one of the branches of geological sciences and one or two minors in fields outside this Department. A candidate could arrange for a major in oceanography with particular interest in geological oceanography beginning next year.

Courses Offered:

GEOLOGICAL OCEANOGRAPHY
Bloom

Shoreline erosion, transportation and deposition; origin and structure of continental shelves and ocean basins. Geologic processes and geomorphic development in the marine environment.

GEOMORPHOLOGY
Bloom

Description and interpretation of land forms in terms of structure, process, and stage.

EARTH SCIENCE
Bloom

Physical geography, including the spacial relationships of the earth, moon, and sun that determine the figure of the earth, time, seasons, atmospheric and oceanic circulation, and climates.

EARTH SCIENCE LABORATORY
Bloom

Observation and calculation of daily, monthly, and seasonal celestrial events, topographical mapping and map interpretation; world climatic regions.

INTRODUCTORY GEOLOGICAL SCIENCES
Philbrick, Staff

Designed to give general students comprehensive understanding of the earth processes, features, and history. Provides the basic knowledge necessary for more specialized courses or a major in geological science. Study of the earth, particularly materials, structure, internal condition, and the physical and chemical processes at work. Principles of interpretation of earth history, evolution of continents, oceans, mountain systems and other features; development of its animal and plant inhabitants.

INTRODUCTORY GEOLOGICAL SCIENCES
Philbrick, Staff

A continuation of the above course.

Person to be contacted for further information:

Robert S. Morison
Director
Division of Biological Sciences
Cornell University
Ithaca, New York 14851

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## LONG ISLAND UNIVERSITY - C. W. POST COLLEGE
Greenvale, New York 11548

### GRADUATE DEPARTMENT OF MARINE SCIENCE

The Department consists of three groups, 1. Marine biology, with concentration in marine microbiology, marine biochemistry, and ichthyology, 2. Geophysical sciences, with concentration in physical oceanography and sedimentation, and 3. Technology, with concentration in ocean engineering and instrumentation. Facilities are now located at the Mitchel Center (a branch of C.W. Post-Merriweather Campus) with 26,000 sq. ft. of teaching and research space, and at the Southampton Campus where there is a seaside marina and marine biology laboratory. The Graduate Department operates a 56 foot ocean going motor sailer, the LUCAYO, a 28 ft. inshore boat, the

ELDON, and several small craft and aircraft. In addition, there is a mobile field laboratory for inshore ecological work.

Instructional Staff:

HUGO D. FREUDENTHAL, Ph.D., Department Chairman, Marine Microbiology
CYRUS ADLER, M.S., Assistant Professor, Physical Oceanography
J. D. BARTON, JR., Ph.D., Associate Professor, Ecology
ALAN C. BERKEBILE, Ph.D., Assistant Professor, Oceanography
PHYLLIS CAHN, Ph.D., Associate Professor, Fish Behavior
GEORGE CLAUS, Ph.D., Associate Professor, Algae Physiology
NICHOLAS COCH, Ph.D., Assistant Professor, Coastal Geology
NORMAN HAMLIN, M.S., Special Lecturer, Ocean Engineering
THOMAS HARESIGN, Ph.D., Assistant Professor, Behavior
DAVID PRICE, M.S., Special Lecturer, Ocean Engineering
ANTHONY UZZO, M.S., Adjunct Assistant Professor, Instrumentation
HAROLD ROMER, M.S., Adjunct Professor, Environmental Engineering
JO ANN JONES, Ph.D., Research Associate
PETER MADRI, Research Associate
CHESTER GREENBERG, Manager of Operations

Degrees Offered:

Master of Science in Marine Science

Students may specialize in biology, geophysical sciences, or technology.

Courses Offered:

### MC 501. MARINE BIOLOGY: LECTURE

Three semester hours of credit. Spring Semester.

An introduction to the life of the sea, covering the physical and chemical environment, methods of study, a survey of the microorganisms and higher plants and animals of the sea, and marine ecosystems.

### MC 502. MARINE BIOLOGY: FIELD AND LABORATORY

Three semester hours of credit. Summer Semester.

Beginning laboratory work in marine biology, in both the laboratory and the natural environment. Special fee, $20.00.

### MC 608, 609. MARINE ECOLOGY: LECTURE AND LABORATORY

Three semester hours of credit each semester. Prerequisite, Marine Science 501, 502. Marine Science 608 required for Marine Science 609. Both summer semesters.

Ecological relationships and trophic levels in the estuarian and marine environments.

### MC 610-611. MARINE MICROBIOLOGY: LECTURE AND LABORATORY

Three semester hours of credit each semester. Prerequisite, undergraduate biology and chemistry.

The taxonomy, morphology, physiology and ecology of marine microorganisms. Special fee, $20.00 each semester.

### MC 622. MARINE BOTANY: LECTURE AND LABORATORY

Three semester hours of credit. Prerequisite, general botany. Summer Semester.

The taxonomy, morphology, physiology, ecology, and economic biology of marine algae. Special fee, $20.00.

### MC 631-632. ICHTHYOLOGY: LECTURE, LABORATORY, AND FIELD

Three semester hours of credit each semester. Both semesters.

The taxonomy, morphology, embryology, physiology, behavior and ecology of fish. Special fee, $20.00 each semester.

### MC 634. MARINE INVERTEBRATE ZOOLOGY: LECTURE AND LABORATORY

Three semester hours of credit. Prerequisite, invertebrate zoology or the equivalent. Fall semester.

The taxonomy, morphology, physiology and ecology of marine invertebrates. Special fee, $20.00.

### MC 636. FISHERIES BIOLOGY: LECTURE AND FIELD STUDY

Three semester hours of credit.

The commercial and biological aspects of fisheries; including methods of estimation of catch, productivity of fishing grounds, migration of fish conservation methods.

### MC 641-642. BIOCHEMISTRY OF MARINE ORGANISMS: LECTURE AND LABORATORY

Three semester hours of credit each semester. Prerequisite, biochemistry and marine microbiology.

The biochemical reactions of marine bacteria, fungi, and protozoa as analyzed with optical, physical, and chemical methods. Special fee, $20.00 each semester.

### MC 643-644. ENVIRONMENTAL POLLUTION

Three semester hours of credit each semester. Both semesters.

The origin, distribution, detection and control of biological and chemical pollutants, and the conservation of terrestrial, aquatic and atmospheric natural resources.

MC 651-652. PHYSICAL OCEANOGRAPHY: LECTURE

Three semester hours of credit each semester. Both semesters.

Extent of the oceans, submarine geology and sedimentation, physical and chemical properties of sea water, radiation and heat flow in the sea. Energy considerations, distribution of temperature, salinity and density. Ice formation and distribution. Sound propagation. Evaporation and precipitation processes, mixing processes, water masses.

MC 653-654. FIELD WORK IN PHYSICAL OCEANOGRAPHY

Three semester hours of credit each semester. Prerequisite, Physical Oceanography. Both semesters.

Methods of collecting and analyzing data, involving time on a deep sea research vessel.

MC 655-656. ADVANCED PHYSICAL OCEANOGRAPHY

Three semester hours of credit each semester. Both semesters.

The hydrodynamic equations, statics and kinematics of ocean currents. Thermohaline circulation in the oceans. Wind waves and swells, tsunamis, and the astronomical tides of the oceans.

MC 661. MARINE GEOCHEMISTRY

Three semester hours of credit. Prerequisites, calculus, general chemistry. Fall semester.

A lecture course beginning with an overall survey of the chemistry of the earth. A detailed study of the chemical processes of the earth and oceans is developed with emphasis on thermodynamics, physical chemistry, crystal chemistry, and phase equilibria.

MC 662-663. MARINE SEDIMENTATION: LECTURE AND LABORATORY

Four semester hours credit. Both semesters.

Sedimentary processes and methods of study of sediments. Marine sedimentary environments, facies and the worldwide distribution of various marine sediment types. Intended for students who have not had courses in sedimentation and stratigraphy. Special fee, $20.00.

MC 681. MARINE INSTRUMENTATION

Three semester hours of credit. Fall semester.

The mechanical and electrical instruments used in marine research: theory, design, operation and limitations.

MC 682. MARINE INSTRUMENTATION

Three semester hours of credit. Spring semester.

A detailed study of the development and design of marine instruments with emphasis on electronic sensor techniques and recording and processing of the data obtained. The course is oriented toward those students who require a detailed knowledge of instrument operation either to pursue development or research activities in the area of marine instrumentation.

MC 691. MARINE OPERATIONS

Three semester hours of credit. Spring semester.

Principles of design, logistics, and legal aspects, so as to make the marine scientists familiar with the problems of vessel operation, maintenance, and staffing.

MC 693-694. OCEAN ENGINEERING: LECTURE

Three semester hours of credit each semester.

Stability of floating bodies. Design of surface and submersible vehicles. Hydrodynamics. Effects of ocean waves on marine structures. Underwater acoustics. Materials for ocean service. Survey of and engineering approach to problems in the exploitation of marine resources.

MC 695-696. ADVANCED OCEAN ENGINEERING: LECTURE

Three semester hours of credit each semester. Prerequisite, Marine Science 693-694 or the equivalent.

Applies and extends the material developed in Marine Science 693-694 within the context of ocean system engineering. Selected examples include a study of subsystem relationships in the design of a deep submersible vehicle; the methods and applications of modeling and simulation; ship dynamic characteristics, maneuvering techniques, and typical control system applications; and the design of experiments for the at-sea evaluation of navigation, ship control systems, and operational doctrine.

MC 701-702. MARINE SCIENCE SEMINAR

One semester hour of credit each semester. Required of all graduate students seeking a Master of Science degree in Marine Science.

Selected topics in marine science presented by guest lecturers, faculty members, and advanced graduate students.

MC 707-708. RESEARCH AND THESIS

Three semester hours of credit each semester. Admission only with sponsorship of a faculty member. Research should be completed within two semesters. Under special circumstances, the time may be extended with the permission of the sponsor and the department chairman; but the student must reregister for Marine Science MC 708 each additional semester.

Selection and supervised investigation of Master's thesis research.

Person to be contacted for further information:

Dr. Hugo D. Freudenthal
Chairman
Graduate Department of Marine Science
Long Island University, Merriweather Campus
P.O. Greenvale, New York 11548

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## NEW YORK UNIVERSITY
Bronx, New York 10453

## DEPARTMENT OF METEOROLOGY AND OCEANOGRAPHY

Current research projects in which students participate include studies of ocean waves, air-sea boundary processes, solar radiation balance, turbulent dye diffusion, large scale ocean circulation, and the equatorial Atlantic. Extensive analogue and digital computing facilities such as an IBM 360/30, BECKMAN 210, and smaller units are available. A sixty-five foot research ship, the KYMA, equipped with AC and DC power, radar, loran, gyrocompass, fathometer, Doppler navigator, deep sea winch, BT winch, dye diffusion gear, skin diving equipment, and data telemetry electronics is used for oceanographic investigations. Applications for graduate assistantships and graduate fellowships are available on request.

Instructional Staff:

JAMES E. MILLER, M.S., Professor of Meteorology, Chairman of the Department
WERNER A. BAUM, Ph.D., Professor of Meteorology (on leave)
GERHARD NEUMANN, Dr. Rer. Nat., Professor of Oceanography
WILLARD J. PIERSON, JR., Ph.D., Professor of Oceanography
RICHARD M. SCHOTLAND, Sc.D., Professor of Meteorology
BENJAMIN DAVIDSON, Ph.D., Professor of Meteorology
JEROME SPAR, Ph.D., Professor of Meteorology
LEO J. TICK, Ph.D., Research Professor of Geophysical Statistics
JAMES P. FRIEND, Ph.D., Associate Professor of Atmospheric Chemistry
KATSUYUKI OOYAMA, Ph.D., Associate Professor of Meteorology
ALBERT D. KIRWAN, JR., Ph.D., Associate Professor of Oceanography
RAYMOND J. DELAND, Ph.D., Research Associate Professor of Meteorology
ALBERT ARKING, Ph.D., Adjunct Associate Professor of Meteorology
ICHTIAQUE S. RASOOL, Dr. Sc., Adjunct Associate Professor of Meteorology
EUGENE E. A. CHERMACK, M.S., Instructor in Meteorology

Degrees Offered:

Bachelor of Science in Meteorology and Oceanography
Master of Science in Oceanography
Doctor of Philosophy

Courses Offered:

Undergraduate Courses

T69.0030-40. INTRODUCTION TO THE GEOPHYSICAL SCIENCES
Kirwan

A historical, descriptive, and physical survey of the earth as a planet, the interior and crust of the earth, the oceans, and the atmosphere. Fundamental concepts and methods of the geophysical sciences. Laboratory includes techniques of meteorological and oceanographic observation.

T69.0050-60. DYNAMIC METEOROLOGY AND OCEANOGRAPHY
Chermack

Thermodynamics and hydrodynamics of the atmosphere and ocean. The equations of fluid motion on a rotating earth. Convection. Wind, waves, currents, and tides. Turbulence in the air and sea. Boundary layer problems.

T69.0051-61. DESCRIPTIVE METEOROLOGY AND OCEANOGRAPHY
Deland

The average state of the oceans and the atmosphere. World climates. General circulation of the air and the sea. Geography and topography of the continents and ocean basins. Properties and distribution of the major air and water masses. Interaction between the sea and the air.

T69.0071. THEORETICAL GEOPHYSICS
Schotland

Theory of elastic and hydrodynamic wave motions in the earth, sea, and air.

**T69.0077. OCEANOGRAPHY I**
Neumann, Pierson

Basic principles and methods of physical oceanography. Dynamic oceanography, ocean currents, waves, and tides. Stratification and general circulation of the oceans. Properties of sea water. Marine geology. Geomorphology of the oceans.

**T69.0087. OCEANOGRAPHY II**
Neumann, Pierson

The ocean environment and its global influence. Interaction between the sea and the air. Marine meteorology and climatology. Marine life and the physical-chemical environment. Organic production in the sea.

**T69.0080. STATISTICAL METHODS IN THE GEOPHYSICAL SCIENCES**
Miller

Applications of statistical methods to problems in meteorology, oceanography, and other branches of geophysics.

## Graduate Courses

**T69.1102. PRINCIPLES OF METEOROLOGICAL AND OCEANOGRAPHIC INSTRUMENTS**
Schotland

Theoretical analysis of meteorological instruments. Application of results of theory to practical problems in the laboratory and in the field.

**T69.1103-1104. THE PLANET EARTH**
Pierson

The major disciplines of geophysics and their interrelationship. The earth as a planet. Tides in the mantle, the oceans, and the atmosphere. The shape of the geoid. Energy sources and exchanges. General circulation of the atmosphere and the oceans. Interactions at boundaries between lithosphere, hydrosphere, and atmosphere. Air masses and water masses. The climate of the atmosphere and the oceans. Paleoclimatology.

**T69.1107. STATISTICAL METHODS IN METEOROLOGY AND OCEANOGRAPHY**
Pierson

Fundamental concepts of probability and methods of statistical analysis. Climatological statistics. Applications of statistical methods to weather forecasting and to research in meteorology and oceanography.

**T69.1151-1152. PHYSICAL OCEANOGRAPHY**
Neumann

Ocean basins and sea bottom. Physical and chemical properties of sea water. Sound and radiation in the oceans. Interaction between the ocean and the atmosphere. Exchange of heat and water between sea and air. The sea surface as a hydrodynamic interface.

**T69.2209-2210. WAVE MOTIONS IN THE ATMOSPHERE AND IN THE OCEAN**
Ooyama

Mathematical introduction to partial differential equations. Perturbation method in hydrodynamics and its applications to atmospheric and ocean waves. Hydrostatic, geostrophic, and other approximations applied to large-scale atmospheric motions. Theories of barotropic and baroclinic instability.

**T69.2215-2216. METHODS OF THEORETICAL METEOROLOGY AND OCEANOGRAPHY**
Kirwan

A review of the methods that have been used to solve problems in geophysical hydrodynamics. Classification of ordinary and partial differential equations. Initial conditions, boundary conditions, and stationary periodic conditions. Methods of solution such as variational techniques, integral transforms, separation of variables, and the method of characteristics. Nonlinear equations and their solution by variational methods, perturbation techniques, and the Poincare-Lighthill-Kuo method. Similarity solutions. Finite difference techniques in the choice of grid size and time step and in the elimination of aliasing, truncation, and roundoff errors. The special functions of mathematical physics including Bessel functions. Legendre polynomials, and hypergeometric functions. Each of the above topics will be illustrated by examples from geophysics such as diffusion of contaminants, wave reflection and refraction, and numerical prediction.

**T69.2222. GEOPHYSICAL RANDOM PROCESSES**
Pierson

Applications of the theory of random processes in geophysics. Concepts of stationarity, ensemble, vector process spectra, cross spectra, bispectra linearity, and non-linearity. Examples from ocean waves, turbulence, large scale atmospheric motions, seismic activity, and long- and short-range weather forecasting.

**T69.2225-2226. GEOPHYSICAL HYDRODYNAMICS**
Davidson

The dynamics of geophysical systems with special emphasis on the atmosphere and oceans. Atmospheric thermodynamics. The hydrodynamic equations for a rotating earth.

T69.2227. DISPERSION OF POLLUTANTS IN THE ATMOSPHERE AND OCEANS
Davidson

Fundamentals of meteorology, oceanography, and climatology as applied specifically to the dispersion of pollutants in the biosphere. The analytic principles of atmospheric propagation, diffusion, and deposition of weapon test debris and reactor effluents are treated. Oceanographic diffusion of materials and its implications for safe disposal of radioactive wastes are explored.

T69.2251. SPECIAL TOPICS IN OCEANOGRAPHY
Neumann, Staff

Review of recent work on selected problems in oceanography.

T69.2253-2254. DYNAMIC OCEANOGRAPHY
Neumann

Dynamics of ocean currents. Conditions in stratified water. The circulation of the oceans. Ocean surface waves. Seiches. Tidal waves. Internal waves.

T69.2255. ESTUARINE HYDROGRAPHY AND FLUSHING PROBLEMS
Neumann

Physical and chemical properties of the water masses of bays, estuaries, and other coastal regions. Dynamics of water movements. Diffusion and turbulence in natural bodies of water. Exchange of water with the open sea. Mixing of water masses and problems of water pollution.

T69.2256. ANALYSIS AND FORECASTING OF OCEAN WAVES
Pierson

The application of time series analysis and hydrodynamics to the measurement and description of the state of the sea. Modern computer technology and the forecasting of waves over the oceans.

T69.2257. OCEANOGRAPHIC ASPECTS OF MAINTENANCE OF BEACHES, HARBORS, AND MARINE STRUCTURES
Neumann

Application of information gained from oceanographic research, including ocean waves, currents, tides, storm tides, and other sea-level changes, to beach erosion problems, off-shore oil drilling, and harbor and marine structures.

T69.2258. SELECTED PROBLEMS IN OCEANOGRAPHY
Staff

Discussion and review of modern work in oceanography.

T69.2259. THE OCEANS
Pierson

Application of the principles of physical and dynamical oceanography to the individual oceans and their special problems. Description of conditions of the various oceans and seas.

T69.2261-2262. OCEANOGRAPHIC FIELD RESEARCH
Neumann, Staff

Practical work at sea with standard oceanographic instruments such as Nansen bottles, reversing thermometers, bathythermographs, current meters, bottom samplers, and specially designed equipment. Participation in oceanographic expeditions.

T69.2263-2264. ANALYSIS OF OCEANOGRAPHIC DATA
Neumann, Staff

Processing of oceanographic observations. Methods of evaluation of records. Presentation and analysis of physical and chemical observations.

T69.2265. MICROCLIMATOLOGY
Davidson

The elements of macro- and microclimate are described. After a brief discussion of the worldwide distribution of macroclimate, the physical causes and the characteristics of the microclimates of coastal regions, lake regions, valleys, the interior of continents and urban areas are described in detail. Particular attention is paid to those elements of microclimate that are important in air-pollution analyses.

T69.2303. RESEARCH METHODS IN METEOROLOGY AND OCEANOGRAPHY
Miller

Lectures and applied work on such topic as selection and delimitation of the research problem, bibliographic research, preliminary experiments, controls and tests, the research record, statistical methods, and the writing of the final report.

T69.2308. RESEARCH IN OCEANOGRAPHY
Staff

Candidates for the master's degree in oceanography meet regularly with the staff advisers to whom they are assigned to report on the progress of their master's theses.

T69.2766. AIR POLLUTION EFFECTS
Staff

The effects of atmospheric pollution on various forms of life, including both direct and secondary effects. Corrosion or contamination of inert matter by pollutants in the atmosphere. Legal aspects and community organization for control of atmospheric pollution.

T69.3309-3310. ADVANCED RESEARCH IN OCEANOGRAPHY
Staff

Candidates for the degree of Doctor of Philosophy who have passed the preliminary examinations in oceanography meet regularly with the staff advisers to whom they are assigned to report on the progress of their doctoral disertations.

SEMINAR

Lectures, group discussions, and reports on modern developments in meteorology and oceanography, by the staff, graduate students, and visiting specialists.

The following are related graduate courses in meteorology frequently taken by students in oceanography:

WEATHER ANALYSIS

ATMOSPHERIC PHYSICS

ATMOSPHERIC RADIATION

ATMOSPHERIC TURBULENCE

WEATHER PREDICTION

RADIOMETEOROLOGY

THE ATMOSPHERES OF THE PLANETS

PHYSICS OF THE UPPER ATMOSPHERE

TROPICAL METEOROLOGY

METEOROLOGICAL MEASUREMENTS BY ROCKETS AND SATELLITES

Person to be contacted for further information:

Professor James E. Miller
Chairman
Department of Meteorology and Oceanography
New York University
Bronx, New York 10453

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## RENSSELAER POLYTECHNIC INSTITUTE
Troy, New York 12181

### DEPARTMENT OF GEOLOGY

Research facilities, including ships, are available for studies in sedimentation and sedimentary petrology at Hudson Laboratories, Columbia University, Dobbs Ferry, New York.

Instructional Staff:

GERALD M. FRIEDMAN, Ph.D., Professor
SAMUEL KATZ, Ph.D., Professor and Chairman
ROBERT G. LaFLEUR, Ph.D., Assistant Professor
DONALD S. MILLER, Ph.D., Associate Professor
RICHARD A. PARK, Ph.D., Assistant Professor

Degrees Offered:

None in marine science. B.S., M.S., Ph.D., in Geology (geo-chemistry, geophysics, sedimentary petrology, sedimentation, paleoecology, paleontology).

Courses Offered:

Geology

T10.09. GEOCHEMISTRY
Miller

Origin and abundance of the chemical elements of the earth and their distribution as related to crystal chemistry. Mineral equilibria. Application of stable and radioactive isotopes to geologic processes.

T10.57. GEOPHYSICS I
Katz

Physical processes in the earth. Seismic gravitational, magnetic and electrical methods.

T10.58. GEOPHYSICS II
Katz

Continuation of T10.57.

G10.59. GEOPHYSICS III
Katz

Elastic and acoustic wave propagation and applications; analysis of earth's magnetic, gravitational, and thermal fields; selected topics.

T10.60. PHYSICAL OCEANOGRAPHY
Katz

Ocean basins; properties of sea water and ice; heat budget and thermal processes; currents, tides and waves; sea-air boundary effects; transmission of acoustic and electromagnetic radiation; instruments and measurements.

G10.70. PROBLEMS IN SEDIMENTOLOGY
Friedman

Physical and chemical properties of sediments, their arrangements in strata, and their later change interpreted in terms of depositional environment and diagenesis.

G10.73. MICROPALEONTOLOGY
Park

Morphology, classification, and geologic significance of animal and plant microfossils. Emphasis on foraminifers, ostracodes, and conodonts.

**G10.74. PALEOECOLOGY**
Park

Principles of paleoecology and their use in paleoenvironmental reconstruction. Laboratory exercises on application of quantitative techniques to paleoecologic problems.

**G10.79. SEDIMENTARY PETROLOGY I**
LaFleur

Processes of transportation and deposition of clastic sediments, environments of sedimentation; cycles, experimental analysis.

**G10.80. SEDIMENTARY PETROLOGY II**
Friedman

Depositional environments of carbonate sediments and their diagenetic alteration. Dolomitization. Laboratory study of carbonate rocks.

Person to be contacted for further information:

Professor Samuel Katz
Department of Geology
Rensselaer Polytechnic Institute
Troy, New York 12181

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## SOUTHAMPTON COLLEGE - LONG ISLAND UNIVERSITY
Southampton, New York 11968

### DIVISION OF NATURAL SCIENCES - Marine Science Major Program

The emphasis of the major program is on sound preparation of the undergraduate in the fundamentals and research techniques of the traditional disciplines, biology, chemistry, geology, mathematics, and physics. Early in his career the student is introduced to the problems of an inter-disciplinary approach to the marine environment as related to his eventual graduate training.

The student is required to complete successfully a minimum of sixty-five semester credit hours of science and mathematics as well as one summer at the marine station.

The Division of Natural Sciences instructional, laboratory and research space approximates 20,000 sq. ft. which includes a one acre campus marine station of 3,000 sq. ft. with docking facilities. Vessels owned and operated by the Division include one 28 ft., two 24 ft. and two 17 ft. boats which are equipped for instructional and appropriate research activity. At present larger vessels are chartered. There are plans to increase the college laboratory and shop space and to procure a larger (45 ft.) vessel in the near future.

Instructional Staff:

W. T. BURKE, Ph.D., Associate Professor, Director of Division
C. A. BERKEBILE, Ph.D., Associate Professor, Geology
G. H. BRILES, Ph.D., Assistant Professor, Chemistry
N. K. COCH, Ph.D., Assistant Professor, Geology
E. I. COHER, Ph.D., Associate Professor, Biology
J. T. DONOHUE, M.A., Assistant Professor, Mathematics (Lt. Commander, U.D.T.,USN)
R. K. FRANKENFIELD, M.A., Instructor, Marine Science
T. C. GUSTAVSON, M.A., Instructor, Geology
T. W. HARESIGN, Ph.D., Associate Professor, Biology
E. T. HENKEL, Ph.D., Assistant Professor, Physics (Lt. Commander, USNR)
H. W. MOELLER, M.A., Instructor, Marine Science
A. SIEGEL, Ph.D., Assistant Professor, Chemistry
J. R. WELKER, M.A., Assistant Professor, Marine Science

Degrees Offered:

B.A. in Marine Science

Courses Offered:

**101 BIOLOGY-SYSTEMATIC BOTANY OF THE LOWER PLANTS**
Moeller

Emphasis on the systematics of marine phytoplankton and attached algae.

**103 BIOLOGY-INVERTEBRATE ZOOLOGY**
Coher

Survey of the classification, anatomy, development, ecology, and phylogeny of invertebrate animals. Emphasis on the marine forms.

**114 CHEMISTRY-INSTRUMENTAL ANALYSIS**
Briles

Emphasis on the theory of instrumental analysis and the use of data applied to the physical and chemical properties of compounds. Prerequisite: Quantitative Analysis.

**171-172 CHEMISTRY-PHYSICAL CHEMISTRY**
Briles

A study of the fundamental theories and laws of physical chemistry.

110-111 NATURAL SCIENCE-OCEANOGRAPHY
Staff

Introduction to the oceans as physical, and bio-geochemical systems. Laboratory and research vessel experience familiarizes the student with instrumentation and methods.

140 BIOLOGY-MARINE ECOLOGY
Welker

A quantitative course with extensive laboratory and field work with local marine and estuarine floral and faunal populations.

190-191 NATURAL SCIENCE-MARINE OPERATIONS AND RESEARCH
Staff

A required summer program of emphasizing technical and applied aspects of marine scientific investigations. Design and execution of simple experimental procedures will be conducted by both groups and individuals.

109 EARTH SCIENCE-METEOROLOGY
Staff

Introduction to the principles of meteorology. Field work conducted both on land and on the water.

103-104 EARTH SCIENCE-STRATIGRAPHY AND SEDIMENTATION
Coch

The basic methods of study of sediments and stratigraphic systems applied to problems arising in engineering, marine science, and geology.

136 EARTH SCIENCE-MARINE GEOLOGY
Coch

Study of marine topography, shoreline development, coastal sedimentary environments and lithofacies; origin and distribution of marine sediments.

193-194 NATURAL SCIENCE-SPECIAL PROBLEMS IN MARINE SCIENCE
Staff

An independent study and research program for upper division students.

197-198 NATURAL SCIENCE-MARINE SCIENCE SENIOR SEMINAR
Staff

Selected topics for reading and discussion. Presentation of individual research conducted during summer session (N.S. 190-191).

Person to be contacted for further information:

Dr. William T. Burke, Director
Division of Natural Science
Southampton College of Long Island University
Southampton, New York 11968

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## STATE UNIVERSITY OF NEW YORK MARITIME COLLEGE
Fort Schuyler, New York, New York 10465

The oceanography laboratory aboard the 10,000 ton training ship EMPIRE STATE IV is well equipped with all standard oceanographic instruments, such as: Nansen bottles, reversing sea thermometers, bathythermographs, infrared thermometers, current meters, inductive salinometers, and turbidity meters. Two courses of instruction in oceanographic observations are offered during the annual ten week cruise periods aboard the training ship.

Instructional Staff:

MEIR H. DEGANI, Sc.D., Professor, Chairman, Science Department
CHARLES THOR, M.S., Associate Professor
DAVID EPSTEIN, Ph.D., Associate Professor
MICHAEL F. DEVINE, A.B., M.S., Instructor

Degrees Offered:

Bachelor of Science in Meteorology and Oceanography

Courses Offered:

Science Department

Undergraduate

Oceanography 303 GENERAL OCEANOGRAPHY I
Degani

Sediments, geomorphology of the ocean bottoms; three dimensional distribution of physical and chemical properties of sea water and their periodic and aperiodic changes; heat budget of the oceans; surface and water masses. Three class hours, three credits.

Oceanography 304E GENERAL OCEANOGRAPHY II
Degani

General circulation of the oceans; regional oceanography; sea ice; propagation of sound and electromagnetic waves; chemical and biological oceanography. Prerequisite: Oceanography 303. Three class hours, three credits.

Oceanography 305 OCEANOGRAPHIC INSTRUMENTS
Devine

Design, installation, care and operation of oceanographic instruments; collection and evaluation of data; use of digital computers. Two class hours, three laboratory hours fortnightly, three credits.

Oceanography 406 APPLIED OCEANOGRAPHY
Epstein

Economic and military oceanography; underwater acoustics; oceanographical engineering; weather ship routing. Prerequisite: Oceanography 413. Three class hours, three credits.

Oceanography 410E

Devine

Investigations of problems in oceanography of special interest to the merchant marine.

Oceanography 413 DYNAMIC OCEANOGRAPHY I

Epstein

Basic hydrodynamic equational theory of currents in a homogeneous and a non-homogeneous ocean; principles of general oceanic circulation. Prerequisite: Meteorology 401. Three class hours, three credits.

Oceanography 414E DYNAMIC OCEANOGRAPHY II

Epstein

Principles of oceanic circulation; interaction between the ocean and atmosphere, surface and internal waves; seiches and tides; statistical theory of ocean waves. Prerequisite: Oceanography 413. Three class hours, three credits.

MARINE METEOROLOGICAL AND OCEANOGRAPHIC OBSERVATIONS I

Thor

One credit.

MARINE METEOROLOGICAL AND OCEANOGRAPHIC OBSERVATIONS II

Thor

One credit.

Person to be contacted for further information:

Dr. M. H. Degani
Chairman, Science Department
State University of New York
Maritime College
Fort Schuyler
New York, New York 10465

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## THE CITY UNIVERSITY OF NEW YORK
New York, New York 10036

Oceanographic training is accomplished through an interdisciplinary program based at the City College campus (138 Street and Convent Avenue, New York, New York 10031). Undergraduate students selecting an oceanography option ordinarily meet the requirements for a major in a science and as seniors take appropriate specialization courses. Concentration programs in biological, chemical, geological, and physical oceanography are available.

At the graduate level, student assignment will vary slightly with the degree objective, and while course work in biological oceanography is offered only at the City College campus, students are encouraged to avail themselves of collateral offerings at all campuses of the City University.

Facilities include: combined library holdings of 1,760,000 volumes and 7,400 periodicals, a collecting boat rigged for shallow water studies, and an IBM 7040 computer and four IBM 1620 computers. The metropolitan area is a rich resource of additional libraries such as those of the City of New York and the American Museum of Natural History. The staff has working relationships with the New York Aquarium, American Museum of Natural History, Haskins Laboratories, Lerner Marine Laboratory (Bahamas), Cape Haze Marine Laboratory (Florida), and Woods Hole Oceanographic Institution, among others. The City University has been participating in the National Science Foundation sponsored oceanographic training program at Duke University Marine Laboratory. The use of an oceanographic research vessel can be arranged.

Instructional Staff: (At the City College campus, unless otherwise stated.)

MARCIA BRODY, Ph.D., Associate Professor (Hunter College), Biophysics of Photosynthesis
M. VERTNER BROWN, Ph.D., Professor, Marine Acoustics
EUGENIE CLARK, Ph.D., Associate Professor, Ichthyology
LEONARD COHEN, Ph.D., Associate Professor, Mathematical Statistics
WILLIAM L. DONN, Ph.D., Professor, Physical Oceanography, Geophysics
JOHN J. FAGAN, Ph.D., Assistant Professor, Paleoecology, Stratigraphy
THOMAS H. HAINES, Ph.D., Assistant Professor, Biochemistry of Algae
MAX HECHT, Ph.D., Professor (Queens College), Sea Snakes
CECIL H. KINDLE, Ph.D., Associate Professor, Paleontology
RAYMOND R. KNOWLES, Ph.D., Assistant Professor, Paleomagnetism, Structural Geology
JOHN LEE, Ph.D., Assistant Professor, Marine Microbiology
KURT E. LOWE, Ph.D., Professor, Petrology, Economic Geology
ELY MENCHER, Ph.D., Professor, Sedimentology, Marine Geology, Petroleum Geology
GERALD S. POSNER, Ph.D., Associate Professor, Plankton Dynamics and Estuarine Hydrography
NICHOLAS M. RATCLIFFE, Ph.D., Assistant Professor, Petrology, Field Geology
RICHARD J. ROMMER, M.S., Lecturer, Meteorology, Physical Oceanography
MARTIN SACKS, Ph.D., Associate Professor, Life History of the Meiobenthos
SIMON SCHAFFEL, M.S., Lecturer, Diatomaceous Sediments, Palynology
ROBERT W. SHIELDS, Ph.D., Assistant Professor, Parasitic Copepods
HAROLD L. STOLOV, Ph.D., Associate Professor, Atmospheric Physics
WILLIAM N. TAVOLGA, Ph.D., Professor, Fish Behavior and Marine Bio-Acoustics
JOHN TIETJEN, Ph.D., Assistant Professor, Ecology of the Meiobenthos

Degrees Offered:

Bachelor of Science
Master of Arts
Doctor of Philosophy

Courses Offered:

Biology

Undergraduate Courses

10. THE LOWER PLANTS
Staff

Structure and life histories of the algae, fungi, and bryophytes.

61. BIOLOGICAL OCEANOGRAPHY
Posner, Tietjen

Study of the biological aspects of the sea.

72. THE INVERTEBRATES
Sacks, Shields, Tietjen

Structure and function of selected invertebrate types.

73. THE VERTEBRATES
Clark

Structural, physiological and behavioral adaptations of the vertebrates.

76. PRINCIPLES OF ECOLOGY
Staff

The interrelationships of organisms with one another and their environment.

98. EXPERIMENTAL BIOLOGY
Staff

A special topics course designed for seniors.

99. SPECIAL PROBLEMS
Staff

Open only to students of exceptional ability and motivation.

Graduate Courses

U706. SYSTEMATICS
Staff

Principles and procedures in botanical and zoological nomenclature and classification, and their relation to current evolutionary concepts.

U724, U790.22 COMPARATIVE ANIMAL BEHAVIOR
Tavolga

The biological basis of animal behavior and comparative behavior of both invertebrates and vertebrates.

U760. ECOLOGY
Staff

Advanced study of the interrelationships between living and non-living.

U761. ADVANCED BIOLOGICAL OCEANOGRAPHY
Clark, Posner

Biodynamics of marine and estuarine waters.

U762. PHYSIOLOGICAL ECOLOGY
Lee

The adaptive physiological specializations of organisms.

U763. EXPERIMENTAL PARASITOLOGY
Shields

An ecological and physiological approach to the study of host-parasite relationships.

U790.6 SEMINAR IN ENVIRONMENTAL BIOLOGY
Staff

U791. COLLOQUIUM
Staff

U792. TUTORIAL
Staff

Studies in areas not covered by formal course work.

1799 and U899. THESIS RESEARCH
Staff

M.A. Thesis and Ph.D. Dissertation.

Chemistry

Undergraduate Courses

12. INORGANIC CHEMISTRY
Staff

Theories of chemical bonding and molecular structure.

30, 31, 32, 33. PHYSICAL CHEMISTRY
Staff

Thermodynamics, kinetics, equilibria, electro- and photochemistry of solids, liquids and gases.

41, 42. QUANTITATIVE ANALYSIS
Staff

Theory and practice of standard, photometric, electrometric and chromatographic methods of analysis.

46. CHEMICAL INSTRUMENTATION
Staff

Basic electronics, principles of instrumentation and applications to modern chemical techniques.

55, 56. ORGANIC CHEMISTRY
Staff

Chemistry of carbon compounds and techniques of their analysis.

59. BIOCHEMISTRY
Haines

Chemistry and metabolism of cellular constituents, modern analytical techniques.

99. RESEARCH
Staff

Selected students, limited enrollment.

## Graduate Courses

U710. ADVANCED INORGANIC CHEMISTRY
Staff

The theoretical and experimental fundamentals of atomic and molecular structure. Emphasis is on physical interpretation.

U750,U751. ADVANCED ORGANIC CHEMISTRY - STRUCTURE, MECHANISM AND SYNTHESIS
Staff

Fundamentals of organic chemical principles, reactions and structures.

U760, U761. ADVANCED PHYSICAL CHEMISTRY
Staff

Systematic development of the theories of chemistry including mathematical development and structural effects and the application of these theories to chemical systems.

U710. (Biochem.) ADVANCED BIOCHEMISTRY LECTURES
Haines

Developments in biochemistry including the major problems in enzymology.

U711. (Biochem.) BASIC LABORATORY TECHNIQUES FOR RESEARCH IN BIOCHEMISTRY
Haines

The theories and applications of modern approaches to the solution of biochemical problems.

## Geology

### Undergraduate Courses

15. GEOCHEMISTRY OF MINERALS
Ratcliffe

Atomic structures and space lattice concepts, fundamentals of x-ray analysis, geochemical aspects of mineral genesis and transformation.

17. INTRODUCTORY METEOROLOGY
Rommer, Staff

Basic principles and causes of weather, interpretation of weather maps and simple forecasting theory.

18. CLIMATOLOGY
Donn, Rommer

Climates of continents and oceans, physical aspects of climatic change, statistical methods and classification.

20. FAUNAL STRATIGRAPHY
Fagan

Fossil faunas and their paleoecology in Paleozoic, Mesozoic, and Cenozoic strata.

21. INVERTEBRATE PALEONTOLOGY
Kindle

Morphology, taxonomy and evolution of fossil invertebrates.

22. OPTICAL MINERALOGY
Ratcliffe, Lowe

Mineral optics and identification of minerals with the polarizing microscope.

24. STRUCTURAL GEOLOGY
Knowles, Staff

Study of the primary and deformation structures of the earth's crust and the forces which produce them.

25. STRATIGRAPHY AND SEDIMENTATION
Mencher, Schaffel

Principles and processes of sedimentation and the resulting stratigraphic and structural units; sedimentary petrography.

32. PETROLOGY
Lowe, Ratcliffe

Origin, formation and occurrence of crystalline (igneous and metamorphic) rocks with emphasis on modern geochemical investigations.

61. INTRODUCTION TO GEOPHYSICS
Donn

Internal structure and constitution of the earth from geophysical studies, principal methods and instruments of geophysical exploration.

64. PHYSICAL OCEANOGRAPHY
Donn, Rommer

Origin and distribution of the oceans, their physical behavior and measurable parameters, atmosphere-ocean interface problems.

HONORS SEMINAR
Staff

Selected students, limited enrollment, topics from geological oceanography.

Graduate Courses

1712. GEOTECTONICS
Knowles

A study of various aspects of the petrology, structural features and stratigraphy of major tectonic elements of the earth's crust.

1714. GEOPHYSICS
Donn

Principles of seismology; elastic constants; properties of elastic waves, gravity and magnetic fields, development of comprehensive earth model.

1740. SEDIMENTOLOGY
Mencher, Fagan

Dynamics of sedimentation, depositional environments, diagenesis and lithification, sedimentary rock fabrics, modern techniques of sedimentary analysis.

1746. GEOCHEMISTRY OF SEDIMENTS
Staff

Chemical aspects of sedimentary rock formation leading to environmental reconstruction and age determination.

1754. PLEISTOCENE GEOLOGY
Staff

Interpretation of the Pleistocene stratigraphic and geomorphic record, sea level changes related to glacial and interglacial climates.

1790. SEMINAR
Staff

Selected aspects of geology not covered in regular courses.

1795. THESIS RESEARCH
Staff

For M.A. Thesis.

Mathematics

Undergraduate Courses

21. MATHEMATICAL STATISTICS
Staff

Probability set functions, random variables, transformation of variables, distribution problems, sampling theory.

91, 92, 93. MATHEMATICS FOR ENGINEERS
Staff

Ordinary differential equations, Fourier analysis, linear algebra, vector spaces and field theory, probability theory.

Physics

Undergraduate Courses

9, 10. MECHANICS
Staff

Rigid body dynamics of particles and systems of particles for plane motion and in three dimensions, translating and rotating coordinate systems.

11, 12-22. ELECTRICITY AND MAGNETISM
Staff

13. THERMODYNAMICS
Staff

Classical thermodynamics, introduction to kinetic theory and chemical thermodynamics.

17. WAVE-MOTION AND ACOUSTICS
Brown

Fundamental vibration theory; composition of vibrations.

55. PHYSICAL METEOROLOGY
Stolov

Physics of the atmosphere, principles of thermodynamics applied to atmosphere, heat, insolation, condensation, precipitation processes.

56. DYNAMIC METEOROLOGY
Stolov

Dynamics of the atmosphere, vector operations, geopotential, radiation, heat balance, diffusion, turbulence, vorticity and perturbation theory.

Person to be contacted for further information:

Dr. Gerald S. Posner
Interdisciplinary Group in Oceanography
The City College
138 Street at Convent Avenue
New York, New York 10031

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## DUKE UNIVERSITY
Durham, North Carolina 27706

The Duke University Marine Laboratory presently occupies fifteen acres of the southern portion of Pivers Island, Beaufort, North Carolina; the U.S. Bureau of Commercial Fisheries Biological and Radiobiological Laboratories encompass the remainder of the Island, the northern end. The present plant consists of eighteen buildings, including three dormitories capable of housing forty-six people, a large dining hall, two residences, boat-house, storehouse for ship's gear, classroom laboratories, and five air-conditioned research buildings. The Laboratory is operated throughout the year.

The station operates a 118-foot research vessel for oceanographic studies, a 55-foot trawler for off-shore investigations, and a 39-foot cabin power boat for trawling and dredging in the surrounding sounds and estuaries. A 17-foot fiberglass speed boat, rowboats with outboard motors and collecting gear are also available.

The Laboratory maintains a workshop and a stockroom of chemicals, glassware, supplies, and equipment.

Course work may be taken at the Laboratory and on the main Durham Campus, but it is recommended that thesis research be done at the Laboratory.

Instructional Staff:

- J. R. BAILEY, Ph.D., Professor of Zoology
- W. D. BILLINGS, Ph.D., James B. Duke Professor of Botany
- C. G. BOOKHOUT, Ph.D., Laboratory Director; Professor of Zoology
- *J. D. COSTLOW, JR., Ph.D., Associate Professor of Zoology
- *D. J. FLUKE, Ph.D., Professor of Zoology and Acting Chairman
- I. E. GRAY, Ph.D., Professor of Zoology
- D. HERON, Ph.D., Associate Professor of Geology
- *E. C. HORN, Ph.D., Professor and Chairman of Zoology
- *W. S. HUNTER, Ph.D., Associate Professor of Zoology
- T. W. JOHNSON, Ph.D., Professor and Chairman of Botany
- D. A. LIVINGSTONE, Ph.D., Professor of Zoology
- G. W. LYNTS, Ph.D., Assistant Professor of Geology
- R. J. MENZIES, Ph.D., Biological Oceanography Program Director and Professor of Zoology
- *H. J. OOSTING, Ph.D., Professor of Botany
- O. PILKEY, Ph.D., Assistant Professor of Geology
- R. B. SEARLES, Ph.D., Assistant Professor of Botany
- U. STEFANSSON, Ph.D., Adjunct Professor of Zoology
- F. J. VERNBERG, Ph.D., Associate Professor of Zoology
- *S. A. WAINWRIGHT, Ph.D., Associate Professor of Zoology
- *K. M. WILBUR, Ph.D., James B. Duke Professor of Zoology
- R. L. WILBUR, Ph.D., Associate Professor of Botany

Degrees Offered:

Separate degrees are not offered in the marine sciences, but a student may pursue work for the A.M. and Ph.D. degrees in Botany or Zoology with concentration of courses in marine biology and oceanography and a thesis in one of these areas. For the A.M. degree in Geology, course work may be taken and a thesis written in marine geology and geological oceanography.

Courses Offered:

Botany

Senior-Graduate

207 MARINE MYCOLOGY

Johnson

Introduction to the structure, classification, culture, and physiology of marine and brackish water fungi. Special problems on groups or individual species. Lectures, laboratory, field trips, introduction to periodical literature, and individual investigations.

211 MARINE PHYCOLOGY

Searles

Classification, taxonomy, morphology, distribution, ecology, and economic uses of marine algae; preparation of herbarium material. In addition to collection, field work will provide students an opportunity to observe associations of marine algae *in situ* by means of diving equipment, if they wish to use it.

220 COASTAL FIELD BOTANY

Wilbur

A floristic survey of the regional flora with attention to the ecological associations of the Beaufort area. Daily field trips will provide the occasion for collection and intensive study of the rich vascular flora.

225-226 SPECIAL PROBLEMS

Staff

Students with adequate training may do special work in various areas in marine botany.

259 THE ENVIRONMENT

Billings

Environmental principles and methods of obtaining and evaluating climatological data for ecological purposes with special attention to instrumentation and microclimate.

Graduate

359-360 RESEARCH IN BOTANY

Staff

Individual investigation in the various fields of botany.

Geology

Senior-Graduate

205 GEOLOGICAL OCEANOGRAPHY

Pilkey

The study of the broad geologic aspects of the ocean basins, including origin, bottom physiography, sediment distribution and sedimentary processes. Observations in the field will be emphasized and will include training in sampling procedures for both shallow and deep water.

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*Involved in the marine science program solely through research and/or student thesis supervision.

222 SEDIMENTARY MINERALS
Heron

Major detrital and authigenic minerals with emphasis on clay minerals.

235 SEDIMENTARY GEOCHEMISTRY
Pilkey

A survey course of the broader aspects of marine geochemistry and the geochemistry of ancient and recent sediments.

241-242 INVERTEBRATE PALEONTOLOGY
Lynts

Biologic and stratigraphic relationships of fossil invertebrates, with special emphasis on evolutionary trends of invertebrates as interpreted from fossil evidence.

243-244 MICROPALEONTOLOGY
Lynts

Microscopic animal and plant fossils, exclusive of spores and pollen, with special emphasis on their biology, taxonomy, evolution, and stratigraphic distribution.

305 PHYSICAL ENVIRONMENTS SEMINAR
Pilkey

## Zoology

### Senior-Graduate

203 MARINE ECOLOGY
Gray

A study of marine animals in relation to environment. Consideration of environmental factors, succession, rhythms, communities, intra-specific and interspecific relations, productivity, conservation, problems, etc., concerned with animal life in the ocean. Lectures, reviews, conferences, field and laboratory work.

214 BIOLOGICAL OCEANOGRAPHY
Menzies

Composition in time and space of marine biosphere in relation to descriptive marine chemistry, physics, and geology. Some work at sea aboard the research vessel.

215 GENERAL PHYSICAL AND CHEMICAL OCEANOGRAPHY
Stefansson

Relief of the ocean floor; physical and chemical properties of sea water; distribution of temperature, salinity, and density; heat budget; sea ice; light; ocean currents, waves and tides; selected topics of regional oceanography. Field work, processing and analyzing of routine oceanographical data, solving problems and interpretation of results.

216 LIMNOLOGY
Livingstone

A study of lakes, ponds, and streams, including their origin, development, geochemistry, energy balance, productivity, and the dynamics of the plant and animal communities living in them. Lectures, field trips, laboratory work.

238 SYSTEMATIC ZOOLOGY
Bailey

The fundamental theory and practice involved in the collection, identification, and classification of animals.

250 PHYSIOLOGICAL ECOLOGY OF MARINE ANIMALS
Vernberg

A study of the physiological responses of marine animals in relation to certain environmental factors and evolution. Animals representing numerous phyla from various habitats are studied.

274 MARINE INVERTEBRATE ZOOLOGY
Bookhout

A study of structure, functions, and habits of invertebrate animals under normal and experimental conditions.

278 INVERTEBRATE EMBRYOLOGY
Bookhout

Lectures, readings, and laboratory work dealing with rearing, development, and life history of invertebrates.

### Graduate

351, 352 DEPARTMENTAL SEMINAR
Staff

A weekly meeting of graduate students and faculty to hear reports and to discuss biological facts, theories, and problems.

353, 354 RESEARCH
Staff

Students who have had proper training may carry on research under direction of members of the staff in various fields.

355, 356 SEMINAR
Staff

One or more seminar courses in particular fields are given each year by various members of the staff.

Person to be contacted for further information:

Dr. C. G. Bookhout, Director
Duke University Marine Laboratory
Beaufort, North Carolina 28516

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## NORTH CAROLINA STATE UNIVERSITY

Raleigh, North Carolina 27601

### DEPARTMENT OF ZOOLOGY

A comprehensive program of research and training in aquatic sciences and marine biology has recently been established. A student's program is patterned to fit his professional interests from a variety of course offerings in zoology, experimental statistics, botany, biochemistry, genetics, sanitary engineering, soil science, biomathematics, microbiology and geology. No degree is offered in oceanography and marine biology.

Several off-campus laboratories are available to students and staff.

(1) The Radiobiological Laboratory at Beaufort, North Carolina, is supported by the Bureau of Commercial Fisheries and by the Atomic Energy Commission. Studies of productivity, cycling of elements through the marine environment, and effects of radionuclides on morphology and physiology of marine organisms are in progress. Modern research laboratories with special facilities for irradiating and maintaining organisms are provided. Six senior scientists at the Radiobiological Laboratory hold adjunct appointments with the Zoology Department and direct the research of graduate students at this laboratory.

(2) The Pamlico Marine Laboratory is a newly established facility near Aurora, North Carolina. The primary research interests encompass the effects of man's activities on the estuarine and marine environment. Current research programs include a study of estuarine circulation using Rhodamine B dye, phosphorus cycling in an estuary in relation to a phosphate mining development, macro- and microdistribution of zooplankton, benthic invertebrate production and distribution, phytoplankton studies including primary productivity and the determination of algal nutrient requirements, a study of bacterial heterotrophy in estuaries, and the physiological effects of fluorides on invertebrates and aquatic plants. The physical facilities include three laboratory buildings, a dormitory and various research vessels; the largest of which is a 35-foot shrimp trawler. One building is furnished with two salt water flow-through systems for the maintenance and culture of estuarine organisms. Two large walk-in coolers are also available for temperature and photoperiod control. Six one-half acre ponds have recently been constructed for experimental work. These ponds are designed to simulate natural estuaries but are subject to environmental control. A large series of smaller pools with flow-through control is also available.

(3) The Hatteras Marine Laboratory is located at the southern end of Hatteras Island, North Carolina, where a wide variety of interesting marine habitats occur. Cape Hatteras is the closest point to the Gulf Stream north of Daytona Beach, Florida. Both northern and southern faunas are found in adjacent waters. Recently the main office-laboratory building was completely renovated. Another building houses a large dissecting room and facilities for maintaining live organisms. Research programs include population dynamics of marine fishes.

A Coastal Studies Institute has recently been provided with funds for a facility to be located on Roanoke Island, North Carolina. Research programs in coastal erosion, beach dynamics and salt marsh productivity will be carried out by faculty and students in the Departments of Botany, Geology and Civil Engineering.

Instructional Staff:

JOSEPH W. ANGELOVIC, Ph.D., Adjunct Assistant Professor, Physiological Ecology
THOMAS W. DUKE, Ph.D., Adjunct Assistant Professor, Radiobiology and Nutrient Cycling in Estuaries
WILLIAM W. HASSLER, Ph.D., Director, Hatteras Marine Laboratory and Associate Professor, Population Dynamics of Marine Fishes
DON W. HAYNE, Ph.D., Professor, Biostatistics and Population Dynamics
JOHN E. HOBBIE, Ph.D., Assistant Professor, Limnology and Plankton Metabolism
DONALD B. HORTON, Ph.D., Director, Pamlico Marine Laboratory and Assistant Professor, Marine Biology and Oceanography
THEODORE R. RICE, Ph.D., Director of the Radiobiological Laboratory, Bureau of Commercial Fisheries and Adjunct Professor, Radiobiology and Marine Ecology
RICHARD B. WILLIAMS, Ph.D., Adjunct Assistant Professor, Plankton Energetics and Productivity
DOUGLAS A. WOLFE, Ph.D., Adjunct Assistant Professor, Biogeochemistry of Marine Waters

Degrees Offered:

Master of Science in Zoology
Doctor of Science in Zoology

Courses Offered:

420 FISHERY SCIENCE I
Hassler

The science of fishery biology; life history and biology of important game and commercial fishes, fishing methods, age and growth analysis, survey of fishery resources, tagging studies, population estimations and pollution studies.

621 FISHERY SCIENCE II
Hassler

An analysis of fishery research methods. Population enumeration and dynamics. The relationship between fluctuations in natural populations and environmental factors.

441 ICHTHYOLOGY
Hassler

The classification and ecology of selected groups of fishes. Lectures, laboratories, and field trips dealing with the systematics, life histories, interrelationship.

### 442 GENERAL ECOLOGY

Cooper, Standaert

The study of relationships between organisms and their environment, and of interactions among organisms. A team-taught course combining the principles of plant and animal ecology. Lectures, laboratories, and field trips present a balanced perspective in environmental biology. Content includes: productivity; physiological ecology; interactions among species; nutrient cycling; pollution; environmental factors affecting freshwater, marine and terrestrial systems; regulation and dynamics of populations; community ecology; world biomes and paleoecology; the ecological viewpoint in modern land management.

### 515 GROWTH AND REPRODUCTION OF FISHES

Hester

Growth and reproduction of fishes. A study of physiology, behavior pathology and genetics as controlling factors of growth and reproduction. Lectures and laboratories will be given and field trips will be taken to research laboratories.

### 517 POPULATION ECOLOGY

Hayne

The dynamics of natural populations. Current work, theories and problems dealing with population growth, fluctuation, limitation and patterns of dispersion, the ecological niche, food chains and energy flow. Emphasis on methods of study.

### 519 LIMNOLOGY

Hobbie

A study of inland waters. Lectures dealing with physical, chemical and biological factors that affect freshwater organisms. General principles are illustrated in the laboratory and on field trips.

### 619 ADVANCED LIMNOLOGY

Hobbie

A study of primary productivity, population interactions, and effects of pollution. An experimental approach is used in the laboratory.

### 529 BIOLOGICAL OCEANOGRAPHY

Horton

A comprehensive course stressing the dynamic interrelationships between organisms in the sea and their physical and chemical environment. The first part will provide a descriptive outline of ocean science including continental and ocean basin origin, ocean basic topography, sediments and their transport; the nature of sea water and its movements; and the adaptations of plankton, benthos and fish life in the sea. Estuarine oceanography will be emphasized. The second part will examine fundamental concepts in biological oceanography and will particularly stress experimental methods.

### 574 PHYCOLOGY

Whitford

An introduction to the classes of algae. The systematic position, life history, and ecology of important genera in the local flora, both freshwater and marine are emphasized.

### 573 ANALYSIS OF WATER AND WASTE WATER

Smallwood

Chemical and physical analysis of water and waste water and interpretation of results.

### 674 STREAM SANITATION

Galler, Smallwood

Biological, chemical and hydrological factors that affect stream sanitation and stream use.

### 567 GEOCHEMISTRY

Brown

The quantitative distribution of elements in the earth's crust, the hydrosphere, and the atmosphere. Application of the laws of chemical equilibrium and resultant chemical reactions to natural earth systems. Geochemical application of Eh-pH diagrams. Geochemical cycles. Isotope geochemistry.

### 590 SPECIAL STUDIES

Staff

The investigation of a particular problem in aquatic biology.

### 690 SEMINAR IN AQUATIC BIOLOGY

Staff

Discussion of current research and literature in limnology and oceanography.

### 699 RESEARCH IN AQUATIC BIOLOGY

Staff

Original research related to a student's thesis.

### 450 INVERTEBRATE ZOOLOGY

Bradbury

### 513 COMPARATIVE PHYSIOLOGY

Staff

### 532 BIOLOGICAL EFFECTS OF RADIATIONS

Grosch

### 550 EXPERIMENTAL EVOLUTION

Mettler

### 537 PHYSIOLOGY OF PLANT CELLS

Troyer

### 511 EXPERIMENTAL STATISTICS FOR BIOLOGICAL SCIENCES I

van der Vaart, Monroe

### 512 EXPERIMENTAL STATISTICS FOR BIOLOGICAL SCIENCES II

van der Vaart, Monroe

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|---|---|---|
| 571 | BIOMATHEMATICS I | van der Vaart |
| 572 | BIOMATHEMATICS II | van der Vaart |
| 401 | GENERAL MICROBIOLOGY | Elkan |
| 552 | SOIL CHEMISTRY | Weed |
| 532 | SOIL MICROBIOLOGY | Bartholomew |
| 570 | SANITARY MICROBIOLOGY | Staff |
| 571 | THEORY OF WATER AND WASTE WATER TREATMENT | Galler |

Person to be contacted for further information:

Dr. Bernard S. Martof, Head
Department of Zoology
North Carolina State University
at Raleigh
Raleigh, North Carolina 27601

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## THE UNIVERSITY OF NORTH CAROLINA
Chapel Hill, North Carolina 27515

Marine science is the name selected by the University of North Carolina for studies in "oceanology", "oceanography", and other environmental studies related to the ocean. Such studies are directed by degree granting departments in the University, and research may be done through the Institute of Marine Sciences at Morehead City.

Departments currently engaged in teaching courses in the marine sciences (oceanology) are Bacteriology, Botany, Chemistry, Environmental Sciences and Engineering, Geology, Physics, and Zoology.

Although specific departments give the degree, courses may be selected by students under the direction of their advisors so as to develop a research project in some phase of marine science. Many courses not available at UNC, but offered at Duke and N.C. State University, may be taken for credit by students at UNC.

Research and teaching facilities for graduate studies in marine sciences are available at the University of North Carolina Institute of Marine Sciences at Morehead City, North Carolina, where there are boats, for estuarine studies, and dormitories. Facilities are being enlarged by a new building under construction. The regional ship of the NSF, operated by Duke University, is a few miles away at Beaufort. Also located at Beaufort is the Duke Marine Laboratory and the laboratory of the U.S. Fish and Wildlife Service. Research facilities are also available at the Wrightsville Marine Biomedical Laboratory at Wilmington, North Carolina.

Some of the courses directed toward graduate studies in marine science which are currently being offered are listed below.

Instructional Staff:

Department of Botany

MAX H. HOMMERSAND, Ph.D., Associate Professor
HELMUT LIETH, Ph.D., Associate Professor
J. FRANK McCORMICK, Ph.D., Associate Professor
CLYDE J. UMPHLETT, Ph.D., Assistant Professor

Department of Chemistry

H. C. THOMAS, Ph.D., Professor
F. N. COLLIER, JR., Ph.D., Associate Professor
M. M. BURSEY, Ph.D., Assistant Professor
J. L. COKE, Ph.D., Assistant Professor

Department of Environmental Sciences and Engineering

CHARLES M. WEISS, Ph.D., Professor
J. DONALD JOHNSON, Ph.D., Associate Professor
EDWARD J. KUENZLER, Ph.D., Associate Professor
LYMAN A. RIPPERTON, Ph.D., Associate Professor
ROBERT A. MAH, Ph.D., Assistant Professor

Department of Geology

ROY L. INGRAM, Ph.D., Professor
VIRGIL I. MANN, Ph.D., Professor
JOSEPH ST. JEAN, JR., Ph.D., Professor
PAUL C. RAGLAND, Ph.D., Assistant Professor
DANIEL A. TEXTORIS, Ph.D., Assistant Professor

Institute of Marine Sciences at Morehead City

ALPHONSE F. CHESTNUT, Ph.D., Professor
WILLIAM E. FAHY, Ph.D., Professor
AUSTIN B. WILLIAMS, Ph.D., Professor
EARL E. DEUBLER, JR., Ph.D., Associate Professor
JAN J. KOHLMEYER, Ph.D., Assistant Professor
HUGH J. PORTER, Ph.D., Assistant Professor
WILLIAM J. WOODS, Ph.D., Assistant Professor

Department of Zoology

CHARLES E. JENNER, Ph.D., Professor
HOWARD T. ODUM, Ph.D., Professor
ALAN E. STIVEN, Ph.D., Associate Professor

Wrightsville Marine Biomedical Laboratory

RALPH W. BRAUER, Ph.D., Director

Courses Offered:

Upper Division Courses

These courses are prerequisite for the Ph.D.

MASC 101 GENERAL OCEANOGRAPHY
Odum

A study of the sea and its processes.

MASC 102 PHYSICAL OCEANOGRAPHY

Physical processes in the sea, including currents, waves, acoustics, optics, and energy flows in the physical processes.

MASC 103 GEOLOGICAL OCEANOGRAPHY
Textoris, Ingram

Geological processes and structures in the sea indlucing study of sedimentation, diagenesis, marine geomorphology, beach dynamics, clay minerals, and the geophysics of the sea floor.

MASC 104 BIOLOGICAL OCEANOGRAPHY
Chestnut

Physical, chemical, and biological factors characterizing estuarine and marine environments emphasizing factors controlling plant and animal populations including methods of analysis, sampling, and identifications.

MASC 105 CHEMICAL OCEANOGRAPHY
Weiss, Johnson

Study of the chemical processes in the sea including the world-wide cycles of major and minor elements, the analytical and physical chemistry of sea water, the generation, diagenesis, and deposition of organic molecules.

MASC 394 Ph.D. DISSERTATION

Additional Courses Available

The following graduate courses are of direct interest to the program. The minor requirement in marine sciences may be met by 18-24 hours selected by the student and his committee from this and the above lists.

Botany

| | | |
|---|---|---|
| 114 | ALGAE | Hommersand |
| 115 | FUNGI | Umphlett |
| 214 | ECOLOGY AND FUNGI | Umphlett |
| 216 | MARINE ALGAE | Hommersand |
| 226 | ALGAL PHYSIOLOGY | Hommersand |
| 241 | AUTECOLOGY | McCormick |

Chemistry

| | | |
|---|---|---|
| 145, 146 | INSTRUMENTAL ANALYSIS | Markham, Knight, Reilley, Murray |
| 168 | STRUCTURAL DETERMINATION IN ORGANIC CHEMISTRY | McKee, Hiskey, Little, Collman, Coke |
| 181, 182 | PHYSICAL CHEMISTRY | Crockford, Morrow, Jarnagin, Dearman |
| 184 | CHEMICAL THERMODYNAMICS | Crockford, Morrow, Thomas, Jarnagin, Dearman |

Environmental Sciences

| | | |
|---|---|---|
| 123 | ANALYTICAL METHODS IN ENVIRONMENTAL CHEMISTRY AND BIOLOGY | Weiss |
| 133 | ENVIRONMENTAL BIOLOGY | Mah |
| 231 | ENVIRONMENTAL MICROBIOLOGY | Mah |
| 232 | LIMNOLOGY AND WATER POLLUTION | Weiss |
| 233 | MICROBIAL ECOLOGY | Man |
| 235 | ECOLOGY OF PHYTOPLANKTON | Kuenzler |
| 247 | CHEMISTRY OF THE TROPOSPHERE | Ripperton |

Geology

| | | |
|---|---|---|
| 109 | ELEMENTS OF GEOPHYSICS | MacCarthy |
| 117 | CLAY MINERALOGY | Ingram |
| 142 | PRINCIPLES OF GEOCHEMISTRY | Ragland |
| 243 | ANALYTICAL GEOCHEMISTRY | Ragland |
| 247 | SEDIMENTATION | Ingram |
| 248 | SEDIMENTARY PETROLOGY | Textoris |

Information Science

| | | |
|---|---|---|
| 100 | FUNDAMENTALS OF INFORMATION PROCESSING | Brooks |

Physics

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|---|---|---|
| 103, 104 | MECHANICS I AND II | Choi |
| 105 | HEAT, THERMODYNAMICS AND KINETIC THEORY | Staff |
| 191, 192 | MATHEMATICAL METHODS OF THEORETICAL PHYSICS | Hubbard |

Statistics

126 INTRODUCTION TO PROBABILITY
Staff

Zoology

108 ECOLOGY
Stiven, McCormick
Leith, Odum

109 INTRODUCTION TO HYDROBIOLOGY
Jenner

126 OCEANOGRAPHY
Odum

140s BIOLOGICAL OCEANOGRAPHY
Staff

141s PROBLEMS IN MARINE BIOLOGY
Staff

146 MARINE ECOLOGY
Jenner

206 ADVANCED INVERTEBRATE ZOOLOGY
Jenner

208A POPULATION DYNAMICS
Stiven

208B METHODS IN POPULATION ANALYSES
Stiven

213 ADVANCED MARINE BIOLOGY
Jenner

Person to be contacted for further information:

Dr. Virgil I. Mann
Professor and Chairman
The University of North Carolina
Chapel Hill, North Carolina 27515

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## OREGON INSTITUTE OF MARINE BIOLOGY
Eugene, Oregon 97403

In affiliation with the University of Oregon, Eugene, Oregon.

The Institute of Marine Biology located on 100 acres of property along Coos Bay at Coos Head has access to abundant and varied marine life due to the number and diversity of habitats relatively unaltered by man. Rich invertebrate and fish faunas are readily available to the student. Commercial fishermen bring unusual catches from deeper water to the station. Over 300 different kinds of marine algae have been listed from the region, and numerous freshwater algae are also available.

The Institute buildings provide dormitories, dining hall, classrooms, and laboratories. There are six laboratory classrooms, with running salt water, study tables and benches, and lamps. The Institute's basic laboratory equipment is supplemented by equipment from the University campus. A working library is available.

The station charters a 36 foot vessel for routine collecting in connection with class and research activities. Students occasionally make arrangements to accompany Charleston fishermen on deep-sea trips.

Instructional Staff:

GERALD J. BAKUS, Ph.D., Visiting Assistant Professor of Biology
STEVEN BROWN, Ph.D., Visiting Assistant Professor of Biology
GRAHAM HOYLE, D.Sc., Professor of Biology (Acting Director)
BAYARD H. McCONNAUGHEY, Ph.D., Associate Professor of Biology (Site Director)
WALTER R. MOBERLY, Ph.D., Assistant Professor of Biology

Degrees Offered:

None. The University of Oregon awards credit, including graduate credit for all courses designated (G), or at the 500 level, for all courses taken at the Institute. Work done at the Institute may form an integral part of the work towards Bachelors, Masters, or Doctors degree in Biology offered on the Eugene campus.

Courses Offered: (Summer 1967)

Bi 461, 462 INVERTEBRATE ZOOLOGY (G) 8
Brown

Survey of representatives invertebrate groups, with emphasis on marine forms; morphology, systematics, life history and ecology.

Bi 463 PARASITOLOGY (G) 4
McConnaughey

Survey of major parasitic groups; biological relationships of parasite and host and effects of such relationships on each.

Bi 476 BIOLOGY OF MARINE ORGANISMS (G) 4
Moberly

Consideration of certain aspects of the physiology of marine organisms in relation to environmental parameters. Comparative physiology of selected groups.

Bi 478 MARINE ECOLOGY (G) 4
Bakus

Ecological concepts and methods with primary reference to marine organisms and situations.

Bi 401, 501 RESEARCH
Staff

Bi 403, 503 THESIS
Staff

Bi 408 LABORATORY PROJECTS
Staff

Person to be contacted for further information:

Director
Oregon Institute of Marine Biology
Department of Biology
University of Oregon
Eugene, Oregon 97403

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## OREGON STATE UNIVERSITY
Corvallis, Oregon 97331

### DEPARTMENT OF OCEANOGRAPHY

Since March 1964, the Department of Oceanography has been housed in a four-story Oceanography Building on the Corvallis campus. This building contains 30,000 square feet of office and laboratory space. The laboratories are well equipped for research in each of the aspects of oceanography stressed in our current program.

Funds have been granted by NSF for building the first addition to the Oceanography Building. The new wing will approximately double the office and laboratory space available for oceanography research and graduate training.

The newly constructed Marine Science Center is located at Newport on the shores of Yaquina Bay, 56 miles west of Corvallis. One of the three wings of the laboratory building houses research in coastal aspects of oceanography and marine biology. The Center also provides shore support and docking facilities for the Department's research vessels and a new marina for small boats.

Two research vessels, the YAQUINA and PAIUTE, comprise the Oregon State University marine science fleet. A third vessel, the CAYUSE, will be added by the end of 1967.

The 180-ft. YAQUINA is capable of carrying out extended cruises anywhere in the oceans of the world. The vessel carries a crew of 17-21, and can accommodate 19 scientists. She houses eight research laboratories and is outfitted with three oceanographic winches and related gear for effective sampling of all kinds. With a cruising range of 6,500 miles, she can remain at sea for more than 30 days.

The PAIUTE, 33 feet long, is of sport fishing design. Completed in 1966, the PAIUTE was built and equipped for scientific studies within about 50 miles of the coast.

The CAYUSE will fill the gap between the functions of the YAQUINA and the PAIUTE. It will be equipped for one to two week cruises out to about 200 miles from the coast. Its crew will number from two to six depending on its mission, and it will carry up to 10 scientists.

Instructional Staff:

WAYNE V. BURT, Ph.D., Sc.D., Department Chairman, Professor, Oceanography
GUNNAR BODVARSSON, Ph.D., Professor, Geophysics and Mathematics
JOHN V. BYRNE, Ph.D., Professor, Geological Oceanography
PETER DEHLINGER, Ph.D., Professor, Geophysical Oceanography
HERBERT F. FROLANDER, Ph.D., Professor, Biological Oceanography
JOEL W. HEDGPETH, Ph.D., Professor, Biological Oceanography
RICHARD Y. MORITA, Ph.D., Professor, Biological Oceanography
CHARLES L. OSTERBERG, Ph.D., Professor, Marine Radioecology
JUNE G. PATTULLO, Ph.D., Professor, Physical Oceanography
HERBERT C. CURL, JR., Ph.D., Associate Professor, Biological Oceanography
JAMES E. McCAULEY, Ph.D., Associate Professor, Biological Oceanography
STEPHEN J. NESHYBA, Ph.D., Associate Professor, Physical Oceanography
KILHO PARK, Ph.D., Associate Professor, Chemical Oceanography
WILLIAM G. PEARCY, Ph.D., Associate Professor, Biological Oceanography
RICARDO M. PYTKOWICZ, Ph.D., Associate Professor, Chemical Oceanography
DAVID TILLES, Ph.D., Associate Professor, Chemical Oceanography
GEORGE F. BEARDSLEY, Ph.D., Assistant Professor, Physical Oceanography
ANDREW G. CAREY, Ph.D., Assistant Professor, Biological Oceanography
WILLIAM O. FORSTER, Ph.D., Assistant Professor, Marine Radioecology
GERALD A. FOWLER, Ph.D., Assistant Professor, Geological Oceanography
JEFFERSON J. GONOR, Ph.D., Assistant Professor, Biological Oceanography
DONALD F. HEINRICHS, Ph.D., Assistant Professor, Geophysical Oceanography
LaVERNE D. KULM, Ph.D., Assistant Professor, Geological Oceanography
RODERICK S. MESECAR, M.S., Assistant Professor, Physical Oceanography
VICTOR T. NEAL, Ph.D., Assistant Professor, Physical Oceanography
G. STEPHEN POND, Ph.D., Assistant Professor, Physical Oceanography
LAWRENCE F. SMALL, Ph.D., Assistant Professor, Biological Oceanography
ROBERT L. SMITH, Ph.D., Assistant Professor, Physical Oceanography
ELIZABETH STRONG, B.A., Assistant Professor, Physical Oceanography
BRUCE WYATT, M.S., Senior Instructor, Physical Oceanography

Degrees Offered:

Master of Arts in Oceanography
Master of Science in Oceanography
Master of Science in Oceanography (Geophysics)
Master of Science in General Science (no thesis required)
Doctor of Philosophy in Oceanography
Doctor of Philosophy in Oceanography (Geophysics)

Students may specialize in any of the following fields: Physical, chemical, biological, radioecological, geological, or geophysical oceanography; geophysics.

Courses Offered:

## Undergraduate Courses

### Lower Division

Oc 133 ELEMENTS OF OCEANOGRAPHY
Pattullo, McCauley

Study of the development of the principles of oceanography by the men who have been pioneers in the field; background of and contributions by these pioneers; ships and equipment used from Polynesian times to the present.

Oc 331 INTRODUCTION TO OCEANOGRAPHY
Frolander, Curl

Elective non-technical course designed to give the student broad general background. Emphasis on relationship between oceanography and other fields.

### Upper Division

Mb 415 MARINE MICROBIOLOGY
Morita

Ecology, function, and importance of microorganisms in the ocean; microbiology of sedimentary processes; low temperature and hydrostatic pressure effects on marine microorganisms.

Mb 416 MARINE MICROBIOLOGY LABORATORY
Morita

Laboratory studies to accompany Mb 415.

G 420 GEOPHYSICAL EXPLORATION
Staff

Physical methods used in mining and oil prospecting; emphasizing geologic interpretation.

GS 431 PHYSICAL LIMNOLOGY
Neal

Physical and chemical processes in lakes and rivers; methods of making physical measurements; some field work.

Oc 432 PHYSICAL OCEANOGRAPHY
Smith

Physical processes in ocean and estuaries.

Oc 433 CURRENTS AND WATER MASSES
Pattullo

Factors contributing to the origin and preservation of the water masses and currents of the oceans; distribution of variables in the sea.

Oc 434 ESTUARINE AND SHORELINE PROCESSES
Neal

Estuarine and nearshore processes; waves, surf and beach effects; tides and tidal currents; types and mechanism of estuarine circulation.

Oc 441 BIOLOGICAL OCEANOGRAPHY
Frolander

Physical, chemical, and biological factors characterizing the marine environment; factors controlling plant and animal populations; methods of sampling, identification, and analysis.

Oc 442 MARINE ZOOPLANKTON
Frolander

Floating animal life in the sea; factors controlling population and production; regional distribution; methods of sampling; identification; nuisance forms.

Oc 451 CHEMICAL OCEANOGRAPHY
Park

Chemical composition and properties of sea water; standard chemical methods for oceanographers; salinity, pH, dissolved gases, nutrients, carbonate cycle, geochemistry, extraction.

GS 461 MARINE RADIOECOLOGY
Osterberg

Artificial radionuclides in the marine environment; measurement; identification; their uptake and transference through marine food chains.

Oc 480 MARINE GEOPHYSICS
Heinrichs

Marine applications of geophysical methods, including seismic, gravity, magnetic, and others.

## Graduate Courses:

G 540 MICROPALEONTOLOGY
Fowler

Collection, preparation, classification, and identification of microfossils; biostratigraphy and ecologic evaluation of fossil foraminiferal assemblages.

Oc 543 MARINE NEKTON
PEARCY

Swimming animals of the oceanic zones of the sea, including squid, fishes, and marine mammals; vertical and horizontal distribution and abundance; food chain relationships; special problems of deep-sea life; methods of sampling

Oc 544 MARINE PHYTOPLANKTON ECOLOGY
Curl, Small

Floating plant life in the sea and estuaries; systematics and distribution; physiology; population dynamics; environmental factors; artificial cultivation; effect upon environment; position in food webs.

### Oc 545 MARINE PHYTOPLANKTON PHYSIOLOGY

Curl

Life processes of plankton algae with emphasis on energy-capturing processes, mineral nutrition, flotation mechanisms, cell division, and evaluation of experimental procedures; problems of existence in the open ocean; artificial production of maximum yields.

### Oc 546 MARINE PRIMARY PRODUCTION

Small

Experimental procedures for measuring primary biological production; evaluation of experimental results and their interpretation.

### Oc 547 MARINE PHYTOPLANKTON SYSTEMATICS

Curl

Classification, identification, and geographic distribution of marine phytoplankton; biometry and problems of speciation; techniques of sampling, preparation of specimens for examination and identification, use of literature.

### Oc 548 MARINE BENTHIC ECOLOGY

Carey, McCauley

Ecology of the marine bottom environment; marine and estuarine bottom communities; effects of the environment on distribution and abundance of fauna; adaptations to the environment; population dynamics.

### Oc 552 CHEMICAL OCEANOGRAPHY

Park

Chemical composition and properties of sea water; standard chemical methods of determining salinity, pH, dissolved gases, nutrients; carbon dioxide and nutrient cycles; chemical equilibria in sea water; organic matter; biogeochemistry.

### Oc 553 DESCRIPTIVE CHEMICAL OCEANOGRAPHY

Pytkowicz

Reasons for the observed distributions and cycles of chemical species in sea water; applications of these distributions to the study of water masses; exchange with the atmosphere; biological production; sedimentation.

### Oc 554 THEORETICAL CHEMICAL OCEANOGRAPHY

Pytkowicz

Thermodynamics of chemical reactions in sea water at atmospheric at high pressures, illustrated mainly by the carbon dioxide-carbonate system; physicochemical properties of sea water.

### Oc 561 GEOLOGICAL OCEANOGRAPHY

Byrne

Structure and morphology of the ocean basins; processes of marine erosion and deposition; sediment types and distribution; marine geological methods and applications. Course designed for non-geologists.

### Oc 565 GEOLOGY OF THE OCEAN BASINS

Byrne

Methods of geological and geophysical measurement in the ocean basins; topographic, geologic, and geophysical nature of the ocean basins; major features occurring in them, origin and development.

### Oc 566 MARINE SEDIMENTATION

Byrne

Sediment collection; sediments in the various marine environments; physical and biological processes affecting sedimentation; chemical deposits; engineering applications of marine sedimentation; recent marine sediments as a key to paleoecology.

### Oc 568 ECOLOGY OF FORAMINIFERA

Fowler

Morphology and physiology of foraminifera; physical, chemical, and biological controls on the distribution and abundance of benthic and planktonic foraminifera; gross population trends; seasonal variations in faunas; applications to other fields.

### Oc 569 DISTRIBUTION OF MODERN FORAMINIFERA

Fowler

Laboratory identification and classification of foraminifera; field and laboratory techniques; use of literature; numerical analysis of faunas; familiarization with bathymetric and zoogeographic index species of benthic and planktonic foraminifera; specialized research problems.

### Oc 571 MARINE HYDRODYNAMICS

Neshyba

Mathematical treatment of motion in the ocean; methods for solving physical problems.

### Oc 572 UNDERWATER SOUND

Smith

Sound transmission; factors affecting sound transmission in the sea; uses of sound; active and passive sonar, SOFAR, Swallow; sediment study; depth determination; navigation.

### Oc 573 WAVES AND TIDES

Beardsley

Cause, nature, measurement, analysis, and prediction of surface waves, tides, and tidal currents; tsunamis; storm surges.

### Oc 580 THEORETICAL GEOPHYSICS, SOUND TRANSMISSION

Staff

Fundamental relations between stress-strain; general theory of wave transmission; shallow water and deep water transmission; reflectivity; attenuation.

Oc 581 THEORETICAL GEOPHYSICS, EARTH GRAVITY
Heinrichs

Internal constitution, gravity field, and gravity potential of the earth; earth ellipsoid; gravity measurements (sea, land, and space); isostasy; reduction of gravity measurements; gravity anomalies; deviations from isostatic equilibrium; convection currents; polar migrations.

Oc 582 THEORETICAL SEISMOLOGY
Bodvarsson

Fundamental elastic wave equations and solutions, including body and surface waves; layered half-space problem; effects of gravity, curvature, and viscosity; wave equations and solutions for plates and cyclinders; wave propagation in medium with variable velocity.

Oc 583 EARTHQUAKE SEISMOLOGY
Dehlinger

Description of earthquakes; types of earthquakes; seismograph theory; seismic ray paths; velocity determination; shallow and deep earthquakes; magnitude and energies of earthquakes; locating earthquakes; microseisms; seismicity.

Oc 584 PHYSICS OF THE EARTH
Bodvarsson

Effects of confining pressure, temperature, time, and solutions on the properties of rocks; the earth and moon in the solar system; source materials and their reliabilities for determining the nature and composition of the earth; composition of the core, crust, and mantle of the earth; processes within the earth with special reference to their effect on earthquakes, isostasy, crustal structure, island arcs.

Seminars - Special Topics

OCEANOGRAPHIC ANALYSIS
Pattullo

THEORETICAL PHYSICAL OCEANOGRAPHY
Neshyba

BOUNDARY OCEANOGRAPHY
Beardsley

PHYTOPLANKTON PHOTOMICROGRAPHY
Curl

PROBLEMS IN COASTAL OCEANOGRAPHY
Smith

APPLIED GAMMA RAY SPECTROMETRY
Osterberg

Oc 501 RESEARCH
Staff

Oc 503 THESIS
Staff

Oc 505 READING AND CONFERENCE
Staff

Oc 507 SEMINAR
Staff

Oceanography Courses for Teachers*

Oc 590x BIOLOGICAL OCEANOGRAPHY FOR TEACHERS
Pearcy

Factors in the marine environment; physical, chemical, biological, and other influences controlling the nekton and plankton populations; general relationships, origin, distribution, and special processes of sea life; methods of sampling and techniques used in studying marine life; some field work.

Oc 591x PHYSICAL OCEANOGRAPHY FOR TEACHERS
Neal

Physical processes in oceans and estuaries; factors contributing to origin of water masses and currents, waves, tides, and tidal currents; some field work.

Person to be contacted for further information:

Dr. Wayne V. Burt, Chairman
Department of Oceanography
Oregon State University
Corvallis, Oregon 97331

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* Credit will not count toward a graduate major in oceanography.

## LEHIGH UNIVERSITY
Bethlehem, Pennsylvania 18015

The Marine Science Center encourages interdisciplinary research in marine science. Being interdepartmental, it provides opportunities for staff and students from the fields of geology, biology, and chemistry to carry out research on problems of common interest. Research in marine geochemistry, biochemistry, microbiology, ecology, physiology, sedimentology, and oceanography is conducted in the Marine Science Laboratories, at sea, and at cooperating marine stations. Laboratories of the Center occupy about 4,400 square feet of space, and these together with those of cooperating departments of the University are equipped for modern research in most fields of marine science.

Instructional Staff:

JAMES PARKS, Ph.D., Geological Oceanography. Director, Marine Science Center; Research Associate Professor of Geology
SAUL B. BARBER, Ph.D., Physiology, Professor of Biology

JOSEPH R. MERKEL, Ph.D., Marine Microbiology, Professor of Biochemistry
J. DONALD RYAN, Ph.D., Sedimentology, Professor of Geology
SIDNEY S. HERMAN, Ph.D., Biological Oceanography, Associate Professor of Biology
HAYDEN N. PRITCHARD, Ph.D., Marine Algae, Assistant Professor of Biology

Degrees Offered:

Graduate programs leading to Master of Science and Doctor of Philosophy degrees, with a strong emphasis on marine sciences, are available in the Departments of Biology, Chemistry, and Geology. Interdepartmental programs can be arranged.

Courses Offered:

## Biology

### Graduate Courses

Biol. 406 BIOLOGICAL SEMINAR

Advanced seminar in current developments including departmental research. Required for all candidates for graduate degrees in the Department. Second semester.

Biol. 407 BIOLOGICAL RESEARCH

Investigations in any phase of the biological sciences according to the student's preparation and interests. First semester.

Biol. 417 MARINE ECOLOGY

An advanced course in the ecology of the marine environment. Study of the physical and chemical factors, organisms and their interrelations. Ecological theory pertaining to population dynamics and energy flow. Two lectures and one laboratory period per week. Prerequisite: Consent of head of department.

Biol. 418 BIOLOGICAL OCEANOGRAPHY

Surveys of marine plant and animal plankton, nekton and benthos. Composition of various groups, productivity, interrelationships of plants and animals and the role of micro-organisms in the sea. Three lectures per week. Prerequisite: Consent of head of department.

Biol. 480 MARINE SCIENCE SEMINAR

An advanced interdisciplinary seminar on various problems of marine science, with visiting speakers and student presentations. May be substituted for Biol. 406. First semester.

## Geology

### Undergraduate Courses

Geol. 63 INTRODUCTION TO OCEANOGRAPHY

A survey of the physical, chemical, biological, and geological nature of the oceans. Two lectures, one recitation. Prerequisite: A laboratory course in science (Biol., Chem., Geol., Phys., or Psych.) First semester.

### For Advanced Undergraduates and Graduates

Geol. 281 GEOLOGICAL RESEARCH

Independent investigation of a special problem in the field, laboratory, or library. Prerequisite: Consent of head of department. First semester.

Geol. 282 GEOLOGICAL RESEARCH

Similar to Geol. 281. May be elected as a continuation or separately. Prerequisite: Consent of head of department. Second semester.

Geol. 310 COMPUTER APPLICATIONS

Geol. 313 SEDIMENTATION

The characteristics of sediments, the processes that control deposition, environments of deposition. Techniques of collection, preparation, and analysis. Lecture and laboratory work. Prerequisite: Geol. 12. First semester.

Geol. 337 SEDIMENTARY GEOCHEMISTRY

Processes controlling the distribution of the elements in the lithosphere, hydrosphere, atmosphere, and biosphere with particular reference to sediments and sedimentary rocks. Prerequisite: Geol. 312 or consent of head of department.

In addition to the above courses for students specializing in marine sciences, a given student must complete all of the usual requirements for a degree in his chosen field of specialty, such as biology, geology, or chemistry. Research is emphasized at all levels of graduate study. There are many opportunities for beginning students to cooperate with the staff on laboratory and field studies. Advanced students are encouraged to undertake independent and interdisciplinary research problems.

A summer research seminar is held at the Bermuda Biological Station. National Science Foundation stipends are available for qualified participants.

Person to be contacted for further information:

Dr. James Parks, Director
Marine Science Center
Lehigh University
Bethlehem, Pennsylvania 18015

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## UNIVERSITY OF PUERTO RICO
Mayaguez, Puerto Rico 00708

### INSTITUTE OF MARINE BIOLOGY

The Institute is a research and graduate (M.S.) training facility with headquarters on the Mayaguez campus and field installations on the 18 acre island of Magueyes, 22 miles from campus. On the island, separated from shore by a narrow channel, there are eight modest structures which house research and teaching laboratories, classrooms, dormitories, shops, storerooms, darkroom, cooking and dining facilities, and a cottage for visiting investigators. Floating equipment includes the 65-ft. R/V CARITE and the 60-ft. R/V MEDUSA, plus the 28-ft. PELICANO, the 16-ft. PHYSALIA II and several skiffs.

Instructional Staff:

LUIS R. ALMODOVAR, Ph.D., Associate Professor, Marine Botany
MAXIMO J. CERAME-VIVAS, Ph.D., Director, Benthic Ecology, Oceanography
CHARLES E. CUTRESS, M.S., Associate Professor, Marine Invertebrates
MANUEL DIAZ-PIFERRER, D.C.N., Associate Professor, Marine Botany
PETER W. GLYNN, Ph.D., Associate Professor, Marine Ecology
JUAN G. GONZALEZ, M.S., Assistant Professor, Planktology, Biological Oceanography
JOHN S. RAMSEY, Ph.D., Assistant Professor, Ichthyology
FERMIN SAGARDIA, Ph.D., Assistant Professor, Biochemistry, Physiology

Degrees Offered:

M.S. in Biology.

Courses Offered:

Advanced Undergraduate and Graduate Courses

552. GENERAL ICHTHYOLOGY
Ramsey

The study of the biology, taxonomy and morphology of fishes with emphasis on the local forms. Field trips.

553. FISHERIES BIOLOGY
Ramsey

The study of the principles and techniques of fisheries research. Field trips.

554. SYSTEMATIC ICHTHYOLOGY
Ramsey

A detailed study of the biology and taxonomy of the fishes of the world, with emphasis on functional morphology.

557. TAXONOMY OF MARINE INVERTEBRATES
Cutress

The study of the invertebrate phyla, using local marine representatives, stressing their taxonomy, biology and ecology.

558. MORPHOLOGY OF MARINE INVERTEBRATES
Cutress, Glynn

The study of the anatomy and morphology of local marine representatives of the invertebrate phyla stressing form and function.

595 S. MARINE ECOLOGY
Glynn, Staff

The study of marine communities and their environment with emphasis on the marine ecosystems. Local fauna stressed. Summer course at marine station.

Graduate Courses

620. PLANKTOLOGY
Gonzalez

The taxonomic and ecological study of the animal and plantktons which constitute the marine plankton around Puerto Rico. Physiology and culture of diatoms, dinoflagellates and some crustacea.

625. MARINE INVERTEBRATE EMBRYOLOGY
Cerame

The study of invertebrate embryology and phylogeny using local marine invertebrates as examples. Field trips. Laboratory rearing of larvae.

652. BIOLOGICAL OCEANOGRAPHY
Gonzalez, Cerame

Marine life and its relationship to physical, chemical and geological factors in the ocean. Field work and demonstrations.

659. MARINE MICROBIOLOGY
Almodovar

The study of marine bacteria and allied organisms, with emphasis on their morphology, taxonomy and ecology. Isolation and pure cultures.

661. MARINE BOTANY
Almodovar

An introduction to the marine flora with emphasis on the morphology, ecology and taxonomy of marine algae.

665. MARINE PHYSIOLOGY
Sagardia

A comparative study of the physiological mechanisms of marine plants and animals stressing their relationships with the environment. Among the topics discussed are osmotic regulation, bioluminescence and photosynthesis.

669. MARINE BIOGEOGRAPHY
Staff

The study of the origin, distribution and speciation of marine plants and animals in relation to physical, chemical and physiographic factors of the marine environment. Special emphasis on tropical faunas and floras.

670. ECOLOGY OF MARINE COMMUNITIES
Glynn

The quantitative structure and composition of marine assemblages and their trophic and energetic relationships.

671. SPECIAL PROBLEMS
Staff

A tutorial discussion, library and/or research work on a special subject.

691, 692. GRADUATE SEMINAR
Staff

Discussion of recent topics in marine sciences and related fields. Students will discuss topics near their areas of specialty.

699. RESEARCH
Staff

Six credits will be granted upon presentation and acceptance of the thesis.

Person to be contacted for further information:

Mrs. Bertha M. Cutress
Administrative Assistant
Institute of Marine Biology
University of Puerto Rico
Mayaguez, Puerto Rico 00708

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## UNIVERSITY OF RHODE ISLAND
Kingston, Rhode Island 02881

### GRADUATE SCHOOL OF OCEANOGRAPHY

The Graduate School of Oceanography, in addition to the usual classroom facilities, has a modern, fully-equipped oceanographic laboratory which was completed in 1960. Two new buildings, one a research library and the other a laboratory-office structure, are under construction and will be ready for occupancy in 1968. They will triple the available space. The school also operates R/V TRIDENT, a 180-ft. research vessel; a 40-ft. dragger, and a 45-ft. power cruiser. The smaller vessels are used in Narragansett Bay and inshore waters along the east coast.

Instructional Staff:

JOHN A. KNAUSS, Ph.D., Dean and Professor
NELSON MARSHALL, Ph.D., Professor
DAVID M. PRATT, Ph.D., Professor
MELVIN E. STERN, Ph.D., Professor
HOWARD E. WINN, Ph.D., Professor
HARRY P. JEFFRIES, Ph.D., Associate Professor
ROBERT L. McMASTER, Ph.D., Associate Professor
SAUL B. SAILA, Ph.D., Associate Professor
JOHN McN. SIEBURTH, Ph.D., Professor
JOHN T. CONOVER, Ph.D., Assistant Professor
JAMES T. CORLESS, Ph.D., Assistant Professor
DALE C. KRAUSE, Ph.D., Associate Professor
THEODORE A. NAPORA, Ph.D., Assistant Professor
THEODORE J. SMAYDA, M.S., Associate Professor
KERN R. KENYON, Ph.D., Assistant Professor
MICHAEL E. PILSON, Ph.D., Assistant Professor
JEAN-GUY SCHILLING, Ph.D., Assistant Professor
AKELLA N. SASTRY, Ph.D., Assistant Professor
GILLES LaROCHE, Ph.D., Adjunct Professor
CARL N. SCHUSTER, Ph.D., Adjunct Professor

Degrees Offered:

Master of Science in Oceanography
Doctor of Philosophy in Oceanography

Both degrees are given with options in physical, chemical, geological, and biological oceanography.

Courses Offered:

Graduate courses to which qualified upperclassmen are admitted:

100 GENERAL OCEANOGRAPHY
Conover

A survey course in the major disciplines in oceanography including geological, physical, chemical, and biological aspects integrated into a conceptual approach to the sciences of the sea.

201 PHYSICAL OCEANOGRAPHY
Knauss

Basic course covering all aspects of physical oceanography. Physical properties of sea water, heat budget, distribution of variables, dynamics, water masses and general circulation. Waves, tides, history and interrelationships with other marine sciences.

### 211 GEOPHYSICAL HYDRODYNAMICS

Stern

Fluid dynamics of rotating bodies with application to earthly phenomena. Figure of the earth. Conservation laws and rotational constraints. Geostrophic and Quasi-Geostrophic motion. Hydrodynamic instability applied to generation of surface gravity waves. Laminar and turbulent Ekman boundary layers. Wind driven ocean circulation caused by density variations.

### 221 CHEMICAL OCEANOGRAPHY

Pilson

A study of the processes regulating the composition of sea water and the distribution of chemical species. The interaction of marine chemistry with the ocean floor, atmosphere, and marine organisms.

### 230 GEOCHEMISTRY

Corless

An introduction to the study of the distribution of the elements in the natural environment. Emphasis is placed upon an understanding of the chemical principles and chemical processes which govern this distribution.

### 231 SEMINAR IN MARINE GEOCHEMISTRY

Corless

Discussion of problems of current interest in marine geochemistry. Reading assignments will be in the scientific literature. A research paper will be required of each student.

### 241 GEOLOGICAL OCEANOGRAPHY

McMaster

Brief survey of marine geology and its relationships to other marine sciences. Growth and destruction of beaches, physical characteristics of continental terraces and theories as to their origin, major features of the vast ocean basins, such as coral reefs, ridges and deeps, and influence of these features on currents and life and sources and distribution of marine sediments.

### 242 PETROGRAPHY OF MARINE SEDIMENTS

McMaster

Principles of sedimentary petrology applied to study of recent marine sediments. Major emphasis on methods of analysis and presentation of analytical data. Processes that lead to deposition of these sediments and environmental forces acting on them once deposited.

### 243 SEMINAR IN DEEP-SEA GEOLOGY

Krause

Class discussion of selected topics in deep-sea geology based on extensive reading in the scientific literature. A research paper by each student and lectures will supplement the discussions.

### 244 THERMODYNAMICS OF THE EARTH'S INTERIOR

Schilling

Review and application of thermodynamics to geological problems. Crystal-melt equilibria, phase transitions, hydration reactions; coprecipitation laws and fractionation processes; effect of the geothermal and pressure gradients, convection.

### 261 BIOLOGICAL OCEANOGRAPHY

Fish

Nature of life in the sea; adaptations, patterns of distribution, and production of plankton, nekton and benthos, their interrelationships and interaction with the environment.

### 262 BENTHOS

Marshall

Bottom environments ranging from the deep ocean to freshwater lakes will be considered. Attention will be directed to the organization of biotic communities and their interrelationships, to trophic dynamics and to critical physical and chemical parameters and change processes involving the benthic biota.

### 264 PHYTOPLANKTON

Smayda

The systematics, ecology, and methods of investigation of the pelagic microscopic plants are considered, including their morphology, adaptations, physiology, succession, production, distribution and regional dynamics as influenced by environmental factors.

### 266 ZOOPLANKTON

Napora

A study of the biology of marine zooplankton, dealing with morphology, adaptation, distribution, physiology, production and interrelationships with other members of the marine biota.

### 267 MARINE BACTERIOLOGY

Sieburth

Present concepts of the distribution, nature, and functions of bacteria and related microorganisms in the marine environment. Methodology will include sampling, culture, taxonomy and study in regard to their physical and physiological ecology.

### 268 FISHERY BIOLOGY

Saila

Biology of fish populations and methods of fishery research, including influence of environmental factors on morphology, physiology, abundance and distribution of fishes, estimation of stocks, growth, aging, mortality, measurement of fish production and theory of fishery regulation.

**273 ADVANCED ANIMAL BEHAVIOR**
Winn

Animal communication with some emphasis on bioacoustics, circadian rhythms, orientation and related topics.

**274 BIOLOGY OF MARINE MAMMALS**
Winn

Migration, reproduction, social organization, classification, anatomy, populations, physiology and communication of cetaceans and pinnipeds.

**291, 292 INDIVIDUAL STUDY**
Staff

Individual study of assigned topics or special problems under one or more members of the staff.

**293, 294 SPECIAL STUDIES**
Staff

Studies of specialized topics in the marine sciences.

**341 RECENT SEDIMENTARY ENVIRONMENTS**
McMaster

Concentrated study of the estuarine, littoral and neritic sedimentary environments with primary emphasis on the relationships between the sediment properties of each environment and its environmental conditions.

**361 ECOLOGICAL CONCEPTS IN MARINE RESEARCH**
Jeffries

Advanced course in ecology with emphasis on marine environment. Ecological theory pertaining to population dynamics, energy in ecological systems and the application of quantitative biology in oceanography. Application of experimental methods in ecological research.

**391 SEMINAR IN OCEANOGRAPHY**
Staff

Students give seminar reports on problems and current research in various areas of oceanography by students. In addition, graduate students in oceanography choose from supporting courses in other departments of the University.

Person to be contacted for further information:

Dr. John A. Knauss
Dean and Professor
University of Rhode Island
Kingston, Rhode Island 02881

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## TEXAS A&M UNIVERSITY
College Station, Texas 77843

### DEPARTMENT OF OCEANOGRAPHY

The Department offers M.S. and Ph.D. degrees in biological, chemical, geological, meteorological, and physical oceanography. It is also possible for certain students with undergraduate degrees in engineering to substitute engineering course work for up to 15 semester hours of prerequisites for the discipline in which advanced work is desired. Such a program usually consists of the regular physical oceanography program with a minor in engineering. Students may also enroll in pertinent courses offered in other departments, e.g.: Geology and Geophysics, Biology, Mathematics and Physics among others. An effort is made to maintain a balance between the biological, chemical, geological and physical aspects of oceanography both in teaching and research.

The Department is housed in two buildings on the main campus of the University. Facilities available to faculty and students include: The Texas A&M Marine Laboratory at Galveston, Texas; the fully equipped 180 foot R/V ALAMINOS.

To date 68 students have completed M.S. degrees and 43 have completed Ph.D. degrees in oceanography.

Instructional Staff:

LEO BERNER, JR., Ph.D., Associate Professor of Biological Oceanography
A. H. BOUMA, Ph.D., Associate Professor of Geological Oceanography
WILLIAM R. BRYANT, Ph.D., Assistant Professor of Geological Oceanography
WILLIAM H. CLAYTON, Ph.D., Professor of Physical Oceanography
JOHN D. COCHRANE, M.S., Associate Professor of Physical Oceanography
SAYED Z. EL-SAYED, Ph.D., Associate Professor of Biological Oceanography
RICHARD A. GEYER, Ph.D., Head and Professor of Department of Oceanography
EDWARD R. IBERT, Ph.D., Assistant Professor of Chemical Oceanography
DALE F. LEIPPER, Ph.D., Professor of Physical Oceanography
WORTH D. NOWLIN, Ph.D., Assistant Professor of Physical Oceanography
WILLIS E. PEQUEGNAT, Ph.D., Professor of Biological Oceanography
ROBERT O. REID, M.S., Professor of Physical Oceanography

Degrees Offered:

Master of Science in Oceanography
Doctor of Philosophy in Oceanography

Courses Offered:

## Undergraduate Courses

### 205 SURVEY OF OCEANOGRAPHY

Staff

Discussion of selected topics in oceanography to provide lay student with broad conception of nature of world ocean, including evaluation of its potential contributions to solution of problems presently confronting mankind. A relatively nontechnical course open to all university students.

### 401 INTRODUCTION TO OCEANOGRAPHY

Staff

Subject matter survey. Discussion of interdisciplinary relationships between biological, chemical, geological, physical, meteorological, and engineering aspects of field. Typical studies. Prerequisite: Approval of instructor.

## Graduate Courses

### 603 SEA LABORATORY TECHNIQUES

Nowlin

Practice in techniques used regularly aboard ship and in collecting field data; cruise planning and execution; processing and analysis of data. Prerequisite: Ocn. 608.

### 608 PHYSICAL OCEANOGRAPHY

Nowlin

Observation; physical properties of sea water; property distributions, heat budget, oceanic water; kinematics; gravity, pressure, hydrostatics, stability, Coriolis force; wave motions; horizontal flow, geostrophy; wind drift; circulation. Prerequisites: Math. 122 or 210; Phys. 219.

### 609 PHYSICAL OCEANOGRAPHY

Nowlin, Cochrane

Advanced treatment of topics introduced in Ocn. 608, including vorticity, turbulent transfer, wind-driven and thermohaline circulation. Prerequisite: Ocn. 608.

### 611 THEORETICAL PHYSICAL OCEANOGRAPHY

Reid

Kinematics and dynamics of fluids; Eulerian and Lagrangian description: thermodynamic considerations of single and multicomponent fluid mixtures; thermal stability; steady circulation. Prerequisites: Math. 601; Met. 435 or Ocn. 609.

### 612 ELEMENTS OF OCEAN WAVE THEORY

Nowlin

Theories of simple harmonic surface waves, capillary waves, and internal waves; wave energy, propagation, modification in shallow water; superposition; waves of finite height. Prerequisite: Math. 601; Ocn. 609; or approval of instructor.

### 613 ENGINEERING ASPECTS OF OCEANOGRAPHY

Reid

Engineering applications of ocean wave theories, including long waves; wave spectra; wave generation and practical wave prediction; wave modification; wave forces. Prerequisite: Ocn. 612 or approval of instructor. (Offered in 1967-68 and in alternate years thereafter.)

### 614 DYNAMICS OF THE OCEAN AND ATMOSPHERE

Reid

Unified linear perturbation theory of rotating stratified fluid with application to ocean and atmosphere; energy considerations; characteristic modes of motion; approximate methods of analysis. Prerequisites: Math. 602; Ocn. 611, 612. (Offered in 1967-68 and in alternate years thereafter.)

### 615 LONG WAVES AND TIDES

Reid

Free and forced surges; seiches; effect of variable depth; WKB and Rayleigh-Ritz methods; method of characteristics; bores; Kelvin and Stokes waves; oceanic tides; cooscillating tides; storm tides. Prerequisites: Math. 602; Ocn. 612. (Offered in 1966-67 and in alternate years thereafter.)

### 616 THEORY OF OCEAN WAVES

Nowlin, Reid

Wave height statistics; wave spectra and their determination; Pierson-Neumann wave forecasting theory; effects of viscosity of surface, gravity waves; wave generation by wind; nonlinear interaction. Prerequisite: Ocn. 612. (Offered in 1967-68 and in alternate years thereafter.)

### 617 THEORIES OF OCEAN CIRCULATION

Nowlin

Theories of wind-driven circulation; Sverdrup solution; frictional and inertial boundary domains; energy and vorticity considerations; role of stratification and bathymetry; theories of thermohaline circulation; model experiments. Prerequisite: Ocn. 611. (Offered in 1967-68 and in alternate years thereafter.)

### 620 BIOLOGICAL OCEANOGRAPHY

Pequegnat

Critical analysis of contribution of biological science to our understanding of sea. Discernible interrelationships between organisms and physicochemical parameters emphasized. Prerequisite: General prerequisites for oceanography.

### 622 ANALYSIS OF BENTHIC COMMUNITIES

Pequegnat

Comprehensive study of marine benthos with principal emphasis upon Gulf of Mexico and Caribbean Sea. Prerequisite: Ocn. 620 or equivalent.

### 623 MARINE ZOOPLANKTON

Berner

Detailed examination of selected aspects of biological oceanography with particular reference to the zooplankton of the Gulf of Mexico and Caribbean. Prerequisite: Ocn. 620 or equivalent.

### 624 MARINE PHYTOPLANKTON

El-Sayed

Detailed studies of phytoplankton with emphasis on physical and chemical factors which affect plankton production; study of phytoplankton-zooplankton relationship; sampling problems. Prerequisite: Ocn. 620 or equivalent.

### 630 GEOLOGICAL OCEANOGRAPHY

Bouma, Bryant

Survey of marine geology; structure and composition of ocean basins and continental margins; chemical and physical properties of marine sediments. Prerequisite: General prerequisites for oceanography.

### 631 GEOLOGICAL OCEANOGRAPHY

Bouma, Bryant

Theory of sediment transport; marine shorelines and processes operating in coastal zones; beach processes; nature of marine sediments. Prerequisite: Undergraduate major in geology or approval of instructor.

### 638 SIMULATION TECHNIQUES

Clayton

Simulation research applications utilizing large general purpose electronic analog computer; problem material from many disciplines but primary emphasis on hydrodynamic model design and solution procedures of ocean-atmosphere interaction. Prerequisites: Math. 308; approval of instructor.

### 640 CHEMICAL OCEANOGRAPHY

Ibert

Chemical composition and properties of sea water; evaluation of salinity; pH, excess base, and carbon dioxide system in sea; marine nutrients; oxygen and other dissolved gases; organic constituents. Prerequisite: General prerequisites for oceanography.

### 641 CHEMICAL OCEANOGRAPHY

Ibert

Selected topics in chemical oceanography including: industrial utilization of sea water; chemical products of marine biota; water freshening; corrosion; photosynthesis and fertility of sea. Prerequisite: Undergraduate major in chemistry or approval of instructor.

### 642 LABORATORY TECHNIQUES IN OCEANOGRAPHY

Ibert

Analytical methods for biological, chemical, and geological investigations. Methods concern salinity, alkalinity, nutrients, organic production, photosynthesis, sediment particle size, trace elements. Prerequisites: Ocn. 608, 620, 630, 640 or approval of instructor.

### 643 GEOCHEMISTRY OF THE OCEAN

Ibert

Study of chemistry of elements in lithosphere, atmosphere, and hydrosphere with emphasis on marine environment. Prerequisite: Undergraduate major in geology or approval of instructor.

### 644 ISOTOPE GEOCHEMISTRY

Ibert

Study of isotope geochemistry of different elements in nature. Evaluation of various age dating techniques. Prerequisite: Undergraduate major in geology or approval of instructor.

### 651 METEOROLOGICAL OCEANOGRAPHY

Leipper

Large scale ocean-atmosphere interaction. Ocean emphasis. Interaction in relation to fog-hurricanes, water and air mass mofification, and elements of circulations of air and water. Prerequisite: Met. 445 or Ocn. 609.

### 652 OCEAN BOUNDARY LAYER PROBLEMS

Clayton, Reid

Theory of turbulent transfer of momentum, heat and moisture; mechanics of turbulence; dispersion; methods of analysis of stochastic time sequences. Prerequisites: Ocn. 611; Stat. 601. (Offered in 1966-67 and in alternate years thereafter.)

### 653 SYNOPTIC PHYSICAL OCEANOGRAPHY

Cochrane

Methods, climatology of the air-sea boundary, evolution of oceanic waters; quasipermanent and varying upper oceanic currents; vertical motions; spreading of waters; abyssal circulation; planetary heat distribution; observational design. Prerequisite: Ocn. 609. (Offered in 1966-67 and in alternate years thereafter)

### 681 SEMINAR I

Staff

Presented by students and based upon their research work and upon surveys of literature.

### 682 SEMINAR II

Staff

Seminar intended for Ph.D., candidates; searching discussions of recent topics in the field: participation by students and staff. Prerequisite: Two years of graduate oceanography work.

### 685 PROBLEMS

Staff

Special topics to suit small group requirements. Deals with problems not within thesis research and not covered by any other course in established curriculum. Prerequisite: General prerequisites for oceanography.

### 691 RESEARCH

Staff

For thesis or dissertation. Topic subject to approval of Department Head.

Person to be contacted for further information:

Richard A. Geyer
Head
Department of Oceanography
Texas A&M University
College Station, Texas 77843

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## UNIVERSITY OF TEXAS
## INSTITUTE OF MARINE SCIENCE
Port Aransas, Texas 78373

The research facilities of the Institute include: 20,000 square feet of research, biological collection, library, and shop space. Most of this is air-conditioned. A laboratory with running seawater is located on a pier over the Aransas Pass inlet. There is a special air-conditioned vibration free laboratory. Twenty concrete and fiberglass experimental ponds are located on the grounds. A variety of small boats including an air-boat and a coring barge are available. Larger boats are the 40' VAGABOND, a modified cabin cruiser, and the 46' LONGHORN, a heavy trawler. The Institute's boat basin is located adjacent to the laboratory buildings.

Instructional Staff:

DONALD E. WOHLSCHLAG, Ph.D., Professor of Zoology. Ecology.
R. W. BEHRENS, Ph.D., Assistant Professor of Geology. Marine Geology. Sedimentation.
B. J. COPELAND, Ph.D., Assistant Professor of Zoology. Pollution Ecology
P. L. PARKER, Ph.D., Assistant Professor of Chemistry. Organic Geochemistry and Marine Chemistry
C. VAN BAALEN, Ph.D., Assistant Professor of Botany. Marine Microbiology. Algal Physiology.
J. A. C. NICOL, Ph.D., Visiting Professor of Zoology. Bioluminescence.

Degrees Offered:

The Master of Science and Doctor of Philosophy degrees are offered through the main campus Departments of Geology, Microbiology, Zoology, Chemistry, Botany and Environmental Health Engineering with a specialty in marine science.

Courses Offered:

### 382.1 MARINE INVERTEBRATES

Staff

Advanced consideration of classification, morphology, development, and natural history of marine invertebrates.

### 382.2 MARINE MICROBIOLOGY

Van Baalen

Isolation and physiology of marine microorganisms and consideration of their role in marine processes.

### 382.3 MARINE GEOLOGY

Behrens

Geological processes and methods for exploring the sea floor. Special emphasis on sedimentation in gulf and bay environments.

### 382.4 MARINE BOTANY

Staff

Biology of marine plants with special reference to those of the Gulf of Mexico.

### 382.5 MARINE ICHTHYOLOGY

Staff

The systematics of fishes, including their major classification, comparative anatomy, embryology, and general distribution.

### 382.6 MARINE CHEMISTRY

Staff

Chemical processes in the sea including organic geochemistry, and consideration of uses of radioactive and stable isotopes.

### 481 BIOLOGICAL OCEANOGRAPHY AND MARINE ECOLOGY

Wohlschlag, Copeland

Study of communities, populations, and biological processes in marine environments. Consideration of environmental influences, productivity, biochemical cycles, and conservation.

680 RESEARCH
Staff

680.1 BIOLOGICAL OCEANOGRAPHY, MARINE ECOLOGY, LIMNOLOGY
Staff

680.2 MARINE MICROBIOLOGY
Staff

680.3 MARINE GEOLOGY
Staff

680.4 MARINE BOTANY
Staff

680.5 MARINE ICHTHYOLOGY
Staff

680.6 MARINE CHEMISTRY
Staff

690 GENERAL MARINE SCIENCE
Staff

An introduction to the science of the sea. Lectures, laboratory, and field work.

Person to be contacted for further information:

Dr. Donald E. Wohlschlag
Director
Institute of Marine Science
The University of Texas
Port Aransas, Texas 78373

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## VIRGINIA INSTITUTE OF MARINE SCIENCE*
Gloucester Point, Virginia 23062

The Institute, a major research teaching center in marine science, is located on deep waters at the York River 30 miles from the mouth of Chesapeake Bay. A second campus at Wachapreague on seaside of Virginia's Eastern Shore provides access to the barrier beaches, lagoons, and marshes of the Atlantic Coast. Facilities include modern, permanent laboratory buildings, a research fleet with regular cruises over the continental shelf and an all year round research program.

All classwork and graduate study is directed by working scientists in the environment of an active marine research program. Modern laboratory and field instruments are available. An electron microscope has recently been added to the laboratory equipment inventory.

Research is being carried on in marine ecology, physiology of marine organisms, pollution problems, microbiology, radiobiology, diseases of shellfish, fish life histories, fishery biology, chemical oceanography, marine geology, meteorology, physical oceanography and parasitology.

Instructional Staff:

Marine Sciences

WILLIAM J. HARGIS, JR., Ph.D., Dean and Professor
JAY DONALD ANDREWS, Ph.D., Professor
MORRIS LEROY BREHMER, Ph.D., Professor
EDWIN BIBB JOSEPH, Ph.D., Professor
WILLARD ABRAHAM VAN ENGEL, Ph.B., Ph.M., Professor
JOHN LANGILLE WOOD, Ph.D., Professor
ROBERT E. LEE BLACK, Ph.D., Professor of Biology and Associate Professor of Marine Science
WILLIAM JACKSON DAVIS, Ph.D., Associate Professor
DEXTER STEARNS HAVEN, M.S., Associate Professor
MAYNARD M. NICHOLS, Ph.D., Associate Professor
JOHN JUDSON NORCROSS, M.S., Associate Professor
MARVIN LEROY WASS, Ph.D., Associate Professor
LANGLEY HARRISS WOOD, Ph.D., Associate Professor
ROBERT SYDNOR BAILEY, M.S., Assistant Professor
WILLIAM GORDON MacINTYRE, Ph.D., Assistant Professor
FRANK OVERTON PERKINS, Ph.D., Assistant Professor
EVON PAUL RUZECKI, M.S., Assistant Professor
KENNETH LOUIS WEBB, Ph.D., Assistant Professor
DEAN PAUL OWENS, M.S., Instructor
JUNIUS ERNEST WARINNER, III, M.A., Instructor
FRANK JOHN WOJCIK, M.S., Instructor
EVELYN CLARE WELLS, M.S., Marine Science Librarian

Degrees Offered:

Master of Arts and Doctor of Philosophy in Marine Science from the College of William and Mary.

Master of Arts and Doctor of Philosophy in Marine Science from the University of Virginia.

Majors in: Biological Oceanography, General Oceanography and Fishery Biology.

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* In affiliation with: College of William and Mary
Williamsburg, Virginia

University of Virginia
Charlottesville, Virginia

Courses Offered:

### 401 INTRODUCTORY PHYSICAL AND CHEMICAL OCEANOGRAPHY

Nichols, Ruzecki, MacIntyre

Physical and chemical properties of the marine portion of the hydrosphere, interaction with the atmosphere, and lithosphere. Special emphasis will be devoted to techniques and instruments employed in chemical and physical oceanography. First semester; lecture and demonstration four hours; five credits. Prerequisites: Chemistry 101, 102; Mathematics 101, 102; Physics 101, 102.

### 402 INTRODUCTION TO BIOLOGICAL AND GEOLOGICAL OCEANOGRAPHY

Staff

Occurrence and distribution of living and fossil marine organisms in relation to biological, chemical, geological, and physical attributes of the marine environment along with considerations of other aspects of the static and dynamic relationships between the hydrosphere and lithosphere. First semester; four hours lecture and demonstration; five credits.

### 403 PROBLEMS IN MARINE SCIENCE

Staff

Supervised projects selected to suit the needs of the advanced undergraduate student. Projects to be chosen in consultation with the head of the student's major department, the supervising professor and the Dean of the School of Marine Science. Acceptable topic outlines and terminal project reports are required. All semesters; hours to be arranged; credit according to performance, maximum four credits.

### 406 INTRODUCTION TO MARINE SCIENCE

Staff

A general introduction to marine science including biological, chemical, geological and physical oceanography. Summer session and extension; lectures, laboratory, and field trips twenty hours per week for eight weeks; five credits.

### 407 BIOMETRY I

Norcross

Application of statistical methods to analysis of pertinent scientific data. Chi-square, "t" test, analysis of variance, regression analysis. Introduction to the use of electronic data processing. Second semester; lecture and laboratory six hours; four credits.

### 410 MARINE AND FRESHWATER INVERTEBRATES

Staff

Classification and identification, adaptation, ecology, life histories. Local marine, estuarine and freshwater forms emphasized. Summer session; lectures, laboratory and field trips twenty hours per week for eight weeks; five credits.

### 412 MARINE BOTANY

Staff

A general introduction to the ecology and systematics of algae and spermatophytes encountered in the marine environment. Summer session; lectures, laboratory and field trips twenty hours per week for eight weeks; five credits.

### 415 MARINE BOTANY--THE FUNGI

Staff

An introduction to the ecology and systematics of the fungi and fungus-like plants encountered in the marine environment. Summer session; lectures, laboratory and field trips, twenty hours per week for eight weeks; five credits.

### 501 MARINE SCIENCE SEMINAR

Staff

The organization and presentation of scientific data. Oral discussion and written outlines and critiques of selected seminar topics are required of all students in the department. All semesters; hours to be arranged; one credit each semester; maximum three credits.

### 502 BIOLOGICAL OCEANOGRAPHY

Langley, Wood, Staff

The concepts of ecology as applied to the marine environment; a description of the physical and chemical properties of marine habitats as they apply to the distribution and growth of populations; the ways in which organisms have evolved behavioral and physio-morphological adaptations to environmental stress; and the nature of man's exploitation of the biotic resources of the sea. Second semester; lectures, recitation and laboratory eight hours; five credits.

### 503 ADVANCED PROBLEMS IN MARINE SCIENCE

Staff

Supervised research projects selected to suit the needs of the graduate student. Projects to be chosen in consultation with the student's major professor and the Dean of the School. Acceptable re-research outlines and project reports are required. Training in specific areas such as marine parasitology, epidemiology and pathology of marine organisms, marine productivity, physiology of algae, experimental design, marine conservation, marine engineering and technology, economics of marine resources and other subjects which staff members are qualified to teach is also offered. All semesters; hours to be arranged; credit according to performance; maximum four credits.

### 504 BIOLOGY OF SELECTED MARINE ORGANISMS

Andrews, Van Engel, Haven

Detailed, advanced study of special groups of marine organisms, such as Mollusca or Crustacea, which are within the special interests and training of particular staff members. Emphasis on organisms of economic importance such as *Balanus*, *Callinectes*, *Crassostrea*. As required; lectures and laboratory six hours; four credits.

### 505 RADIOBIOLOGY

Brehmer, Warinner

A study of the principles of tracer techniques procedures for radio-assay, limitations of tracer methodology, hazards, safe handling procedures with particular emphasis on the use of isotopes in marine research. As required; lectures and laboratory six hours; four credits.

### 506 BIOLOGY OF PLANKTON

Staff

The structure and dynamics of estuarine plankton communities, with emphasis on the local biota; classification, morphology and ecology of major constituents; planktological methods. As required; lectures, recitation and laboratory six hours; four credits.

### 507 MARINE MICROBIOLOGY

Wood

Morphology, physiology, ecology, taxonomy, methods of isolation, cultivation and identification of aquatic microorganisms with emphasis on those from the marine environment. As required; lectures and laboratories six hours; four credits. Prerequisites: Biology 301, 302, Chemistry 301, 302.

### 508 ICHTHYOLOGY

Joseph

A detailed treatment of the biology of fishes including phylogeny and classification, functional morphology, speciation, respiration and reproduction. As required; lectures, laboratory and field trips six hours; four credits. Prerequisites: 13 credits in biology including Comparative Anatomy of Vertebrates.

### 509 PHYSICAL OCEANOGRAPHY

Nichols, Ruzecki

Physical properties of sea water, interaction with the atmosphere, movements of water masses and dynamics of currents, waves and tides. Special emphasis on coastal and estuarine waters. As required; lecture, demonstration, laboratory and cruise six hours; four credits.

### 510 POLLUTION BIOLOGY

Behmer

Study of the various types of pollutants, domestic and industrial wastes, soils, insecticides and radioactive materials and their effects on the marine environment. As required; lecture and laboratory six hours; four credits.

### 511 GEOLOGICAL OCEANOGRAPHY

Nichols

Topography and structure of the sea floor, origin of the ocean basins, coral reefs, continental shelves, submarine canyons, depositional environments and sedimentary processes. As required; three hours lecture and cruise; three credits. Prerequisites: General or Physical Geology.

### 512 PARASITES OF MARINE ORGANISMS

Hargis, Staff

Ecology, morphology, systematics and physiology of symbiotes (parasites) occurring in or on marine organisms. Principles of epidemiology and effects of parasites on their host populations will be discussed. As required; lecture and laboratory six hours; four credits.

### 513 MARINE BIOGEOGRAPHY

Wass

A survey of biogeographic regions, their geological origin and present distribution of plants and animals. Major habitats are covered with studies on exogenous and endogenous factors involved and criteria for determining zonation. As required; lecture three hours; three credits.

### 514 LITTORAL PROCESSES

Staff

Physical and chemical processes in the nearshore environments including littoral waves, tides, currents, transportation of sediments and the formation of sedimentary features. As required; lecture and field work five hours; three credits. Prerequisite: Marine Science 401 and consent of instructor.

### 515 EMBRYOLOGY AND ANATOMY OF MARINE INVERTEBRATES

Black

The comparative embryology and adult anatomy of local representatives of all major phyla will be considered. Emphasis will be placed on the evolutionary relationships between groups. Experiments to illustrate possible mechanisms of fertilization, cleavage and organ differentiation will be performed. As required; lectures and laboratory six hours; four credits. Prerequisites: 13 credits in biology.

516 ADVANCED PHYSICAL OCEANOGRAPHY
Staff

Dynamics of ocean currents, turbulence, wind currents, waves, water masses and curiculation of the ocean. As required; lecture three hours; three credits. Prerequisites: Marine Science 401, Mathematics 201, 202, 203, 302, Physics 207, 208, 302.

517 BEHAVIOR OF MARINE ORGANISMS
Wood

A survey of physiological and ecological correlates of behavior with emphasis on marine organisms and their environment; a critical review of behavioral theory; electrophysiological demonstrations of the interaction of sensory processes and environmental stimuli. As required; lecture and laboratory six hours; four credits. Prerequisites: Biology 101, 102, Marine Science 401, 402.

518 MARINE FISHERY SCIENCE
Davis, Joseph

Principles and techniques; including the theory of fishing, age and growth, methods of defining stocks, catch statistics, description of world fisheries, and life histories of selected species. As required; lecture, laboratory and field trips six hours; four credits.

519 BIOMETRY II
Van Engel

Advanced biometrical techniques. Correlation, multiple regression and analysis of covariance; absolute, relative and instantaneous rates of mortality and growth; computations of yield; relation of recruitment to size of stock. As required; lecture and laboratory six hours; four credits. Prerequisite: Biometry I or equivalent.

520 COMPARATIVE ANIMAL PHYSIOLOGY
Mangum, Wood

Survey of major physiological processes, with emphasis on invertebrate organisms. (Jointly with Biology 520) Second semester; lectures; three credits. Prerequisite: acceptable course in physiology.

521 CHEMICAL OCEANOGRAPHY
MacIntyre, Brehmer

Introductory study of chemical processes in marine waters including composition of sea water, nutrients, carbon dioxide systems. As required; lecture three hours, laboratory and cruise two hours; four credits. Prerequisites: Chemistry 101, 102, 201, 202 or equivalent, Mathematics 101, 102 or 103, 104, Physics 102.

522 COMPARATIVE ANIMAL PHYSIOLOGY LABORATORY
Mangum, Wood

Selected exercises which illuminate basic physiological functions. Emphasis is given marine organisms. (Jointly with Biology 522) Second semester; laboratory, four hours; two credits. Prerequisite or corequisite: Marine Science 520.

523 TOPICS IN APPLIED MARINE SCIENCE
Staff

Supervised individual and group consideration of various aspects of applied marine science, such as utilization, development and conservation of marine resources; application of findings of marine science to society's problems; interactions of society, government and marine science; techniques for marine resource management; decision making; problems and techniques of communicating scientific and technological information; economics of marine resource use; sociological and political problems associated with marine resources; legal aspects of marine resource use; international marine resource problems. All semesters; hours to be arranged; credit according to arrangement and performance; maximum four credits.

560 THESIS

Original research in marine science, marine fisheries biology or marine resource management and development. Project to be chosen in consultation with the student's major professor and the Dean of the School. All semesters; hours to be arranged.

Person to be contacted for further information:

Dr. William J. Hargis, Jr.
Director
Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

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## WALLA WALLA COLLEGE
College Place, Washington 99324

Four laboratory buildings provide the following research laboratories: a general laboratory divided into research cubicles, a photoperiod laboratory for studies which must run under controlled environment conditions, a physiology research laboratory, and a small general purpose laboratory. In addition, the Marine Station operates a 40' research vessel and a smaller 26' cruiser which is available for research use. Also, a number of smaller boats are available.

Instructional Staff:

JOHN F. STOUT, Ph.D., Associate Professor of Biology and Director of Marine Station
DONALD F. BLAKE, Ph.D., Assistant Professor of Biology
CARL A. FORSS, Ph.D., Assistant Professor of Biology

ALBERT E. GRABLE, Ph.D., Assistant
  Professor of Biology
DONALD W. RIGBY, M.A., Associate
  Professor of Biology and Head of
  Biology Department

Degrees Offered:

B.A. and B.S. in Biology
M.A. in Biology (program may be
  concentrated in marine biology)

Courses Offered:

Undergraduate Courses

427 COASTAL FLORA
Grable

A study of the classification and ecological relationships of vascular plants of the coastal region of Puget Sound. Special emphasis is given to such habitats as the salt marsh, estuary, coastal forests, and island flora.

429 LIMNOLOGY
Blake

A study of the factors responsible for the presence of distribution of animals and plants in fresh waters and estuaries.

461 INVERTEBRATE ZOOLOGY
Forss

A study of the classification, morphology, ecology, physiology, and natural history of invertebrates.

462 ICHTHYOLOGY
Stout

A study of the classification, ecology, physiology, morphology, etc. of fishes.

463 MARINE BOTANY
Visiting Professor

A study of the marine flora of the Puget Sound region emphasizing the marine algae.

467 BIOLOGICAL OCEANOGRAPHY
Forss

A study of the geology, geography, and biology of the ocean.

468 COMPARATIVE PHYSIOLOGY
Stout

A comparative study of the physiology and life processes of animals with emphasis on the marine invertebrates.

Graduate Courses

524 MARINE INVERTEBRATES
Forss

An advanced study of invertebrate animals with emphasis on marine forms.

Person to be contacted for further information:

Dr. John F. Stout
Director, Marine Station
Biology Department
Walla Walla College
College Place, Washington 99324

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## UNIVERSITY OF WASHINGTON
Seattle, Washington 98105

### DEPARTMENT OF OCEANOGRAPHY

Graduate education in the Department of Oceanography leads to a broad and thorough understanding of the interrelated biological, chemical, geological, and physical processes in the sea, while developing competence in research specialities by intensive classroom, library, laboratory, and field work. The interests of the teaching and research faculties of the Department cover the entire field of oceanography, and the academic and research programs are closely integrated to offer a stimulating educational experience. Students will find strong supporting courses in the other science departments on campus, and there are opportunities for research jointly sponsored by this and other departments.

Students entering graduate work in oceanography should have a degree in a science.

The Department has three research vessels, from 65 to 208 feet long, which berth at the Department pier on campus. A new research building and staging and docking facilities have recently been occupied. Other adjacent facilities include the Fisheries - Oceanography library, research computer center, tidal models of Puget Sound, and experimental electronic and machine shops. The use of the Friday Harbor Laboratories and various charter vessels are also available.

Currently there are research programs in the Arctic Ocean, Black and Caribbean seas, and the Marshall Island area, as well as in Puget Sound, inshore waters of British Columbia, and the Northeast Pacific Ocean.

Biological studies include field and laboratory investigations of the ecology of phytoplankton, zooplankton, nekton, and benthic plants and animals; associated problems of sampling, small-scale distribution, and abundance; autecological and community studies including community metabolism; taxonomic interest in polychaetes, barnacles, pelagic copepods and euphausiids.

Chemical studies include field and laboratory investigations of the properties of seawater and its analysis. Chemical processes in the environment and their interaction with physical, biological, and geological processes are emphasized. Special areas of study include nutrient cycles, gases dissolved in seawater, oxygen-deficient and sulfide-bearing environments, trace metals and organic compounds in the sea.

Geological studies include investigations of particulate matter in the oceans, micropaleontology, volcanology, diagenesis of sediments, processes of sediment transport and deposition, petrology, mineralogy and chemical composition of sediments, the morphology of the deep-sea floor and continental margins, heat flow, acoustic properties of sediments, and seismic reflection.

Research in physical oceanography covers a wide range of problems which are investigated theoretically, in model studies, and by work at sea with buoys and ships. Study is actively pursued on processes important in systems of many different sizes, ranging from Lake Washington to Puget Sound, and entire oceans. Examples include: heat, salt, and oxygen budgets; transport and diffusion associated with major river discharge in the sea; dynamics of estuarine circulation; generation and propagation of internal waves; time-dependent ocean circulation; bathymetric effects on ocean currents; thermohaline circulation; transient current systems; and sea ice studies.

Instructional Staff:

RICHARD H. FLEMING, Ph.D., Chairman of the Department and Professor, Physical Oceanography
GEORGE C. ANDERSON, Ph.D., Research Associate Professor, Biological Oceanography
KARL BANSE, Ph.D., Professor, Biological Oceanography
CLIFFORD A. BARNES, Ph.D., Professor, Physical Oceanography
LEE C. BENNETT, Ph.D., Assistant Professor, Biological Oceanography
ROLF BOJE, Ph.D., Visiting Scientist, German Research Association Fellow, Biological Oceanography
ROBERT E. BURNS, Ph.D., Research Associate and Chief of the ESSA Complement of JOHG, Geological Oceanography
LAWRENCE K. COACHMAN, Ph.D., Associate Professor, Physical Oceanography
JOE S. CREAGER, Ph.D., Professor and Associate Dean, College of Arts and Sciences, Geological Oceanography
RICHARD C. DUGDALE, Ph.D., Research Professor, Biological Oceanography
ALYN C. DUXBURY, Ph.D., Research Assistant Professor, Physical Oceanography
RONALD J. ECHOLS, M.S., Research Assistant Professor, Geological Oceanography
T. SAUNDERS ENGLISH, Ph.D., Associate Professor, Biological Oceanography
M. GRANT GROSS, Ph.D., Associate Professor, Geological Oceanography
MICHAEL L. HEALY, Ph.D., Research Assistant Professor, Chemical Oceanography
DORA P. HENRY, Ph.D., Research Associate Professor, Biological Oceanography
JAMES C. KELLEY, Ph.D., Assistant Professor, Geological Oceanography
LAWRENCE H. LARSEN, Ph.D., Research Assistant Professor, Physical Oceanography
JOYCE C. LEWIN, Ph.D., Associate Professor, Biological Oceanography
HSIN-YI LING, Ph.D., Research Assistant Professor, Geological Oceanography
CLIVE R. B. LISTER, Ph.D., Research Assistant Professor, Geological Oceanography.
WILLIAM B. McALISTER, Ph.D., Visiting Assistant Professor, Physical Oceanography
DEAN A. McMANUS, Ph.D., Assistant Professor, Geological Oceanography
Y. RAMMOHANROY NAYUDU, Ph.D., Research Associate Professor, Geological Oceanography.
ERLING J. ORDAL, Ph.D., Professor, Microbiology, Biological Oceanography
DAVID M. [illegible], Ph.D., Research Associate, Biological Oceanography
MAURICE RATTRAY, JR., Ph.D., Professor, Physical Oceanography
FRANCIS A. RICHARDS, Ph.D., Professor and Assistant Chairman, Chemical Oceanography
GUNNAR I. RODEN, M.S., Senior Research Associate, Physical Oceanography
J. DUNGAN SMITH, M.S., Visiting Assistant Professor, Geological Oceanography
PETER B. TAYLOR, Ph.D., Assistant Professor, Biological Oceanography
JOHN T. WHETTEN, Ph.D., Assistant Professor (Joint Appointment with Geology), Geological Oceanography

Degrees Offered:

Bachelor of Arts, Bachelor of Science, Master of Science, and Doctor of Philosophy in Oceanography.

Courses Offered:

Undergraduate

101 SURVEY OF OCEANOGRAPHY
Bennett, English, Taylor

Origin and extent of the oceans; nature of the sea bottom; causes and effects of currents and tides; animal and plant life in the sea. Recommended for non-majors.

100H SURVEY OF OCEANOGRAPHY-HONORS
English

Origin and extent of the oceans; nature of the sea bottom; causes and effects of currents, waves, and tides; animal and plant life in the sea. Not for oceanography majors. Prerequisites: College of Arts and Sciences Honors Program and permission.

110-111-112 LECTURES IN OCEANOGRAPHY
Fleming

Weekly lectures, demonstrations, and tours to familiarize students with the subject matter and opportunities in oceanography. May be entered any quarter.

198H LOWER-DIVISION TUTORIAL--HONORS

Research with a departmental program. Prerequisites: College of Arts and Sciences Honors Program and permission.

203 INTRODUCTION TO OCEANOGRAPHY
Fleming

A description of the oceans and their relation to man; physical, chemical, biological, and geological aspects of the sea; areal distribution and seasonal cycles of properties; currents; factors affecting populations. Demonstrations and some classes aboard ship and in laboratories. Prerequisites: one year of mathematics, chemistry, and two quarters of physics.

280H INTRODUCTION TO OCEANOGRAPHY-HONORS
Fleming

Descriptive and regional oceanography covering the physical, chemical, biological, and geological aspects of the sea. For science majors. Prerequisites: sophomore standing in College of Arts and Sciences Honors Program and permission.

360 METHODS AND INSTRUMENTS IN OCEANOGRAPHY

Theory and practice of instrumental measurement and sampling oceanography; shipboard equipment, position finding, and selected information on equipment design and properties of materials, calibration and observation of the behavior of typical instruments. Prerequisites, 203, Mathematics 125, one year of physics.

380H UPPER-DIVISION TUTORIAL--HONORS

Research under faculty supervision. Prerequisites, junior standing in College of Arts and Sciences Honors Program and permission.

385 THE OCEANS I

Application of basic scientific principles to water on the surface of the earth. Institute for high school teachers. Open to selected participants only. Held at Skagit Valley College. (Subject to N.S.F. approval each year.)

386 THE OCEANS II

Application of basic scientific principles to the solid earth and its atmosphere. Sequential institute for high school teachers. Open to selected participants only. Prerequisite: 385. Held at Skagit Valley College. (Subject to N.S.F. approval each year.)

401, 402 GENERAL PHYSICAL OCEANOGRAPHY I, II
Barnes, Coachman

Physical properties and processes; theories and methods involved in ocean currents, waves, and tides. Not open to physical oceanography majors. Prerequisites, for 401, one year of chemistry, one year of physics, Mathematics 126; 401 for 402.

404J INTRODUCTION TO GEOPHYSICS: THE OCEAN
Coachman

Composition and character of sea water; physical, chemical, and geological properties and processes; dynamics; waves. Primarily for majors in the geophysical sciences. Offered jointly with Geophysics. Prerequisites: Mathematics 324, Physics 371, Chemistry 170, or permission.

405 GENERAL GEOLOGICAL OCEANOGRAPHY
Creager

Shorelines and nearshore sedimentation; structure and morphology of the continental terrace and deep-sea floor; sediment types and distribution; marine geological methods and applications. Not open to majors in geological oceanography. Prerequisites: 402 or 411 and 412 (or concurrent registration), Geology 205 or 310.

410 PHYSICAL OCEANOGRAPHY
Barnes, Coachman

Physical properties, processes, and the theory of the distribution of variables in the sea; mass and energy budgets. Prerequisite: 404J or graduate standing.

411 OCEAN TIDES AND WAVES
Rattray

Cause, nature, measurement, analysis, and prediction of tides and tidal currents and surface waves. Prerequisite: 404J, Mathematics 238, Physics 222, or graduate standing.

412 OCEAN CURRENTS
Barnes, Coachman

Characteristics of currents and of forces that establish and modify them; methods of direct measurement and computation, use of indirect techniques; associated distributions of mass and properties. Prerequisites: 410, Mathematics 126, Physics 123.

415 FUNDAMENTALS OF UNDERWATER ACOUSTICS
Sands

Vibrating strings, bars, and membranes; plane and spherical acoustic waves; transmission and reflection at boundaries. Prerequisites: 402 or 410, Mathematics 126 or 136H, or permission.

416 APPLICATIONS OF UNDERWATER ACOUSTICS
Sands

Transducers and arrays, absorption and refraction in sea water, sound channels and bottom effects, ambient noise, scattering, passive and active tracking, acoustic telemetering. Prerequisite: 415.

421-422 CHEMICAL OCEANOGRAPHY
Richards

Physical and chemical properties of sea water and marine products; processes determining the chemical make-up of the oceans. Prerequisite: 401 or 404J (or concurrent registration in one.)

423, 424 CHEMICAL OCEANOGRAPHY LABORATORY
Richards

Laboratory problems in the analytical and physical chemistry of sea water and marine materials. Prerequisites for 423: 421, Chemistry 221; for 424: 422 and 423. 423 and 424 may be taken concurrently with 421 and 422 respectively.

433 BIOLOGICAL OCEANOGRAPHY: ORGANISMS AND PROCESSES
Lewin

Marine organisms with emphasis on bacteria, the microscopic plants, the protozoa, and smaller animals; biological processes affecting the sea. Recommended for non-biologists. Prerequisites, 203, Zoology 111 or Biology 101-102, or permission.

434 BIOLOGICAL OCEANOGRAPHY: ORGANISMS AND ENVIRONMENTS
Taylor

Organisms of the plankton, nekton, and benthos; their adaptations to ocean environments and their relationships to each other. Prerequisites, 203, and 15 credits in biological sciences.

435 BIOLOGICAL OCEANOGRAPHY: QUANTITATIVE ASPECTS
Banse

Quantitative distribution in time and space of pelagic and bottom organisms in the open ocean and on the shelf; rates of processes. Prerequisites, 433 or 434 or permission.

440 UNDERGRADUATE SEMINAR
Fleming

Reviews of history and literature; description of local waters and applications of oceanography. Prerequisite, senior standing.

443 REGIONAL OCEANOGRAPHY
Fleming

Application of modern methods to the comprehensive description of selected areas of the oceans. Prerequisite, advanced senior standing.

450 GEOLOGICAL OCEANOGRAPHY
Creager

Shore processes; structure and morphology of the continental terrace and deep-sea floor; marine sedimentary deposits and stratigraphy; geological history of ocean basins and sea water. Prerequisites, major in geological oceanography or geology, 402, or 411 and 412 (or concurrent registration), or permission.

452 SEDIMENTARY PROCESSES

Origin, transportation, and deposition of marine sediments; composition of sediments and sedimentary minerals; marine sedimentary environments; physical and chemical aspects of sedimentary processes. Prerequisites, Geology 326, Chemistry 160.

453 SEDIMENTARY TECHNIQUES
McManus, Whetten

Survey of laboratory techniques for analysis of mineral and chemical composition of sediments; measurement of size, shape, and density of particles; and investigation of mass properties. Methods of data presentation. X-ray diffraction analysis. Prerequisites, 452 (which may be taken concurrently), Mathematics 281.

454 BIOGENIC SEDIMENTS
Echols

Ecology and systematics of plant and animal groups contributing to Neogene marine sediments. Emphasis on microfossils. Prerequisites, 433 or 434, and 450 or Geology 326, 330, or permission.

456 ACOUSTIC AND SEISMIC TECHNIQUES
Bennett

Acoustic data-taking techniques; analysis and interpretation of acoustic bathymetry and seismic reflection and refraction data. Prerequisite, 416 or permission.

460 FIELD EXPERIENCE IN OCEANOGRAPHY
Duxbury

Practical work on shipboard and ashore by participation in regular oceanographic operations on the THOMAS G. THOMPSON and other vessels; chemical, physical, biological, and geological analyses; preparation of reports. 2 credits for field work portion (required of Bachelor of Science candidates). 1 to 4 credits for analyses and report preparation (optional). 2 credits offered every quarter; 6 credits offered Summer and Autumn Quarters only. Prerequisites, 402 or 412, 433 or 434, and 435; 405 or 450; 423, and permission.

461 APPLICATIONS OF OCEANOGRAPHY
Fleming

Analysis of special cases involving application of oceanography to practical problems. Prerequisite, a physical or biological science major or permission.

480H UNDERGRADUATE RESEARCH-HONORS

Independent research. Prerequisites, 180H or 380H, and permission.

482H FIELD EXPERIENCE-HONORS

Participation in extended oceanographic field operations on a research vessel; data analysis and reduction, report preparation. Prerequisites, 380H or 480H, and permission.

483H UNDERGRADUATE THESIS-HONORS

A theoretical or experimental contribution to oceanography. Prerequisites, 480H, and permission.

499 UNDERGRADUATE RESEARCH

Research on assigned topics which may involve laboratory work, field work, or literature surveys. 1 credit required of Bachelor of Science candidates. Prerequisite, permission.

Graduate Courses

511, 512, 513 MARINE HYDRODYNAMICS I, II, III
Rattray

Methods for solving problems in physical oceanography. Prerequisite, a major in a physical science.

515 WAVES
Rattray

Application of marine hydrodynamics principles to wave motion in oceans. Prerequisite, 513. (Offered only in odd-numbered years.)

516 OCEAN CIRCULATION
Rattray

Hydrodynamic theories concerning origin and characteristics of major ocean currents. Prerequisite, 513. (Offered only in even-numbered years.)

517 OCEANOGRAPHY OF INSHORE WATERS
Barnes, Rattray

Theories and techniques of investigation and interpretation of conditions existing in inshore waters with particular reference to mixing and flushing and to areas adjacent to the state of Washington; use of dynamic models. Prerequisite, 512. (Offered only in odd-numbered years.)

518 SEMINAR IN PHYSICAL OCEANOGRAPHY
Barnes, Rattray

Lectures, discussions, and field and laboratory work on selected problems of current interest. Prerequisite, permission.

519 INTERACTION OF THE SEA AND ATMOSPHERE

Interchange of heat, water, and energy; study of budgets and of mechanisms of exchange. Prerequisites, 410, Atmospheric Sciences 462.

520 SEMINAR

521 SEMINAR IN CHEMICAL OCEANOGRAPHY
Richards

Lectures, discussions, and readings on selected problems of current interest. Prerequisite, permission.

523 ADVANCED PROBLEMS IN CHEMICAL OCEANOGRAPHY
Richards

Field and laboratory work on selected problems of current interest. Prerequisites, [illegible] and permission.

530 MARINE PRIMARY PRODUCTIVITY
Anderson

General concepts of marine phytoplankton production; laboratory and field studies; critical examination of special problems. Not open to students who have taken 534. Prerequisites, 433 or 434, and 435 and permission.

531 SEMINAR IN BIOLOGICAL OCEANOGRAPHY
Banse, English, Lewin, Taylor

Lectures, discussions, and field and laboratory work on selected problems of current interest. Prerequisite, permission.

532 MARINE MICROBIOLOGY
Ordal

Ecology and biochemistry of marine bacteria. Prerequisites, Microbiology 400 and permission.

533 ZOOPLANKTON ECOLOGY

Adaptations, modifications, and life histories of animals in the plankton. Evaluation of methods and techniques used in field and laboratory studies. (Offered only in even-numbered years at Friday Harbor Laboratories.) Prerequisite, permission.

534 PHYTOPLANKTON ECOLOGY

Contemporary problems in marine phytoplankton investigations. Evaluation of methods used in field and laboratory studies. (Offered only in even-numbered years at Friday Harbor Laboratories.) Prerequisite, permission.

### 535 ADVANCED PLANKTON ECOLOGY
Banse

Factors controlling the distribution, abundance, and production of plankton organisms; methods of sampling and analysis of standing stock. Prerequisite, permission.

### 536 BENTHOS ECOLOGY
Taylor

Quantitative consideration of the population of the sea-bed. Discussion of modern methods of sampling and analysis. Factors affecting production. Prerequisite, permission.

### 537 ENVIRONMENTAL PHYSIOLOGY OF MARINE MICROALGAE
Lewin

Culture and nutrition of marine unicellular algae; use of algal cultures for the study of problems in biological oceanography. Prerequisite, permission of instructor.

### 550 SEMINAR IN GEOLOGICAL OCEANOGRAPHY
Bennett

Lectures, discussions, and field and laboratory work on selected problems of current interest. Prerequisite, permission.

### 551 MARINE SEDIMENTS I: PARTICLE SIZE, SHAPE, AND DENSITY
McManus

Principles and techniques of measuring particle size, shape, and density; methods of data presentation; interpretation of environmental significance of these properties in marine sediments. Prerequisites, 452 (which may be taken concurrently), Mathematics 281.

### 552 MARINE SEDIMENTS II: MINERAL ANALYSIS
Whetten

Identification and analysis of detrital and authigenic minerals with emphasis on optical and x-ray diffraction techniques. Prerequisite, Geology 423.

### 553 RESEARCH TECHNIQUES IN MARINE GEOCHEMISTRY

Analytical techniques and instruments applicable to problems of marine geochemistry. Prerequisite, Chemistry 351.

### 554 RESEARCH TECHNIQUES IN MARINE GEOLOGY
McManus

Planning field programs; selection of equipment and survey procedures; collection, analysis, compilation, and presentation of bathymetric and sediment data; evaluation of techniques and results. Prerequisites, 450; 453 or 551, and 552 (which may be taken concurrently.)

### 555 MARINE GEOCHEMISTRY

Topics in geochemistry of the ocean and marine sediments. Prerequisites, Chemistry 351 and permission.

### 556 ADVANCED MARINE GEOLOGY
Creager

Contemporary problems in marine geology; concepts supporting or at variance with accepted hypotheses; discussion of recent advances. Prerequisite, permission.

### 557 SUBMARINE VOLCANISM AND DEEP SEA SEDIMENTS
Nayudu

Petrography and petrology of submarine volcanics and deep sea sediments; the origin, distribution, and interpretation of environments and paleoclimatic significance. Prerequisite, permission.

### 600 RESEARCH

### 700 THESIS

### 702 DEGREE FINAL

Limited to students completing a non-thesis degree program.

Person to be contacted for further information:

Dr. F. A. Richards
Assistant Chairman
Department of Oceanography
University of Washington
Seattle, Washington 98105

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## UNIVERSITY OF WASHINGTON
Seattle, Washington 98105

## COLLEGE OF FISHERIES

Facilities include a building with facilities for research in freshwater and marine biology which includes an experimental fish hatchery and salt water aquaria, a 270-acre research facility off campus, a natural stream, an intertidal area, and a 67-foot vessel fully equipped for research work at sea.

Facilities particularly oriented toward problems of food from the sea are the Food Sciences Cobalt 60 research Food Irradiator and equipment for studying and producing fish meal and fish protein concentrate.

Instructional Staff:

CLARENCE DALE BECKER, Ph.D., Research Assistant Professor
MILO CARSNER BELL, B.S., Professor

DONALD E. BEVAN, Ph.D., Associate Dean, Associate Professor
KELSHAW BONHAM, Ph.D., Research Associate Professor
GEORGE W. BROWN, Ph.D., Associate Professor
ROBERT L. BURGNER, Ph.D., Associate Professor
KENNETH KENDALL CHEW, Ph.D., Research Associate Professor
ALLAN CLARK DeLACY, Ph.D., Professor
LAUREN RUSSEL DONALDSON, Ph.D., Professor
PAUL E. FIELDS, Ph.D., Professor
DONALD W. HAGEN, Ph.D., Assistant Professor
EDWARD EMIL HELD, Ph.D., Research Professor
MAX KATZ, Ph.D., Research Associate Professor
JOHN LISTON, Ph.D., Professor
JAMES E. LYNCH, Ph.D., Professor Emeritus
JACK MATCHES, Ph.D., Research Assistant Professor
OLE ALFRED MATHISEN, Ph.D., Associate Professor
GERALD J. PAULIK, Ph.D., Associate Professor
GEORGE M. PIGOTT, Ph.D., Assistant Professor
WILLIAM FRANCIS ROYCE, Ph.D., Associate Dean, Professor
JAMES B. SADDLER, Ph.D., Research Assistant Professor
ERNEST OLAVI SALO, Ph.D., Associate Professor
ALLYN H. SEYMOUR, Ph.D., Professor
LYNWOOD S. SMITH, Ph.D., Assistant Professor
ALBERT KIRK SPARKS, Ph.D., Professor
FRIEDA B. TAUB, Ph.D., Research Associate Professor
RICHARD VAN CLEVE, Ph.D., Dean, Professor
ARTHUR DONOVAN WELANDER, Ph.D., Professor

Degrees Offered:

Bachelor of Science in Fisheries
Fisheries Science Option

Bachelor of Science in Fisheries
Fisheries Management & Administration Option

Bachelor of Science with a major in Fisheries

Bachelor of Science with a major in Food Science

Master of Science

Doctor of Philosophy

Courses Offered:

101 INTRODUCTION TO FISHERIES SCIENCE

Identification, distribution, and life histories of selected fish and shellfish; commercial and recreational fishing; utilization of fisheries products; problems faced in fisheries conservation and management. Recommended for nonmajors.

240 APPLICATIONS OF DIGITAL COMPUTERS TO BIOLOGICAL PROBLEMS
Bevan

Methods and procedure for processing biological data by means of digital computers; problem analysis, elementary programming, use of package programs for statistical analysis.

311 BIOLOGY OF FISHES

Diversity in the structure, function, and habits of fishes viewed as an expression of variations in their biological and physical environment.

314 METHODS AND INSTRUMENTS FOR FISHERY INVESTIGATIONS
Salo

Theory and practice of instrumentation and sampling in fisheries; shipboard experience with equipment, collecting and recording data from biological samples, and the physical environment.

373 FISHERIES OF THE WORLD
Van Cleve

Fisheries in relation to the distribution, abundance, and productivity of fishes; exploitation and problems of development, conservation of aquatic resources.

380 PRINCIPLES OF FISHERIES TECHNOLOGY
Liston

Composition of fish; biochemical and microbiological changes in fish postmortem, nature and effects of processing procedures; current technological developments.

401 THE COMPARATIVE ANATOMY AND CLASSIFICATION OF FISHES
Welander

The comparative anatomy, classification, identification, and distribution of fishes.

405 ECONOMICALLY IMPORTANT MOLLUSCA
Sparks

Classification, life histories, distribution methods of cultivation, and economic importance of oysters, clams, scallops, abalones, cephalopods, and other molluscs.

406 ECONOMICALLY IMPORTANT CRUSTACEA
Sparks

Classification, life histories, distribution, methods of capture, and economic importance of crabs, shrimps, lobsters, crayfish, and the smaller crustacea.

410 ZOOGEOGRAPHY OF FRESHWATER FISHES

Distribution of freshwater fishes with special emphasis on the historical and ecological factors governing present distribution.

445 LIFE HISTORY OF MARINE FISHES
DeLacy

Fecundity, spawning, incubation, and hatching of marine fishes; identification and survival of larvae and juveniles; food and feeding of adults; migration; recognition of subpopulations.

451 REPRODUCTION OF SALMONID FISHES
Donaldson

Spawning and incubation; natural and artificial methods of hatching and rearing, rates of development; racial strains and selection; evaluation of procedures; design, structure, and maintenance of facilities.

452 NUTRITION AND CARE OF FISHES
Donaldson

Basic nutritional requirements of fish in natural and artificial environments; feeding and efficiency of diet; nutritional diseases; stocking policies; quality evaluation.

454 COMMUNICABLE DISEASES OF FISHES
Sparks

Organisms causing diseases in fishes; prevention and known treatments of fish diseases.

456 PRINCIPLES OF MANAGEMENT OF NATURAL RESOURCES
Bevan

Concept of renewable resources; fundamentals of population dynamics; data collection, storage, retrieval, and processing. Practice with simulated resource utilization.

457 PRINCIPLES OF MANAGEMENT OF NATURAL RESOURCES
Mathisen

Management alternatives; the relationships between research and management; case history studies of managed and mismanaged resources. Practice with computer simulation of resource utilization.

460 WATER MANAGEMENT AND POLLUTION STUDIES
Bell

Stream flows and mechanics of freshwater environment, and other problems such as natural propagation; water flow measurement in streams and pipes; use of weirs; hatchery water requirements; screening of water diversions for protection of downstream migrants; nomenclature, water rights and protective laws.

465 PROBLEMS IN FISH BIOLOGY

Taxonomy, ecology, and life history of the fishes of the San Juan Islands and Northeast Pacific. (Offered at Friday Harbor Laboratories Summer Quarter only.)

471 PRINCIPLES OF AQUATIC RADIOECOLOGY
Seymour

The nature, detection, measurement, differential biological effects, and evaluation of the hazards of ionizing radiations.

472 METHODS OF AQUATIC RADIOECOLOGY
Seymour

Methods of radiobiological analyses, of accumulation and loss of radionuclides, and of radionuclides as tracers in aquatic organisms.

473 RADIONUCLIDES IN THE AQUATIC ENVIRONMENTS
Seymour

The distribution of natural and artificial radionuclides, the allowable concentrations, and the biological cost of introducing radionuclides in aquatic environments.

495 INTRODUCTION TO FISHERIES AND FOOD SCIENCE LITERATURE

Directed training in searching bibliographic sources.

499 UNDERGRADUATE RESEARCH

Individual research within the College of Fisheries or on-the-job training in governmental or industrial fisheries organizations.

501 ON-THE-JOB TRAINING

Guided on-the-job training in governmental or industrial fisheries organizations.

503 SYSTEMATIC ICHTHYOLOGY
Welander

Principles and procedures of ichthyological taxonomy demonstrated by current problems and research.

505 RESEARCH TECHNIQUES IN SHELLFISH BIOLOGY
Sparks

A field and laboratory course dealing with research methods in the reproduction, growth, and mortality of oysters and clams.

506 SHELLFISH SANITATION
Sparks, Matches

Problems of the shellfish industry with emphasis on chemical and microbiological contamination and control during culture, harvest, and processing.

507 TOPICS IN FISH ECOLOGY

Selected topics in the ecology of marine and freshwater fish and shellfish; factors affecting survival and migration; definition and distribution of fish populations.

510 FISH BEHAVIOR
Fields

Behavior related to sensory-motor equipment. Design of experiments emphasized for studies ranging from naturalistic observation to controlled laboratory and field experiments.

511 FISH BEHAVIOR LABORATORY
Fields

515 FISH PHYSIOLOGY
Smith

A survey of the functions of the organic system of teleost fishes.

516 FISH PHYSIOLOGY LABORATORY
Smith

Selected experimental techniques in fish physiology.

520 GRADUATE SEMINAR

Training in methods of searching fisheries literature.

530 BIOLOGICAL PROBLEMS IN WATER POLLUTION

Biological and ecological changes in the aquatic environment resulting from domestic, industrial, radioactive, and agricultural wastes and methods for their evaluation.

540 APPLICATION OF DIGITAL COMPUTERS TO PROBLEMS IN AQUATIC ECOLOGY
Bevan, Paulik

Laboratory problems adapted to special interests of the student. Consideration of the simulation of aquatic communities, analysis of aquatic populations, and ecological changes.

556 INTRODUCTION TO QUANTITATIVE POPULATION DYNAMICS
Paulik

Simple analytic approaches to population management; applications of parent-progeny models and logistic models; biological and economic yields of natural populations; analysis of population data on high-speed digital computers.

557 THEORETICAL MODELS OF EXPLOITED ANIMAL POPULATIONS
Paulik

Mathematical representation of basic population processes such as growth, mortality, natality, and mobility; application of optimization technique to yield models. Laboratory work on digital computer.

558 ESTIMATION OF POPULATION PARAMETERS

Statistical analysis of population data; design and analysis of mark-recapture experiments on natural populations; laboratory work on digital computer.

## FOOD SCIENCE

481 INTRODUCTION TO FOOD TECHNOLOGY
Liston

Chemical and biological properties of foods; principles of processing, storage, distribution, and spoilage.

482 FOOD ANALYSIS I

Proximate analysis of foods by physical and chemical methods.

483 FOOD ANALYSIS II

Analysis of foods for vitamins, fatty acids, other biological substances, and additives by physical, chemical, and microbiological methods.

484 PRINCIPLES OF FOOD PROCESSING I
Liston

Unprocessed foods, their composition, nutritional availability, associated microorganisms, storage, and distribution.

485 PRINCIPLES OF FOOD PROCESSING II
Pigott

Principles of food preservation by thermal processes, low temperature methods, chemical methods, irradiation, and other modern processes.

486 DETERIORATIVE PROCESSES IN FOODS
Liston

Biochemical, microbiological, physical, and chemical changes occurring in foods.

487 FOOD ANALYSIS III
Liston

Quality assessment of foods including spoilage methods, rancidity methods, organoleptic and microbiological methods.

504 PRINCIPLES OF TECHNOLOGICAL RESEARCH IN FOOD
Liston

A lecture and laboratory course designed to familiarize graduate students with the methods used in technological research.

521 GRADUATE SEMINAR IN FOOD SCIENCE

Lectures and discussions of current problems and current research in food science.

Person to be contacted for further information:

Dr. R. Van Cleve
Dean
College of Fisheries
University of Washington
Seattle, Washington 98105

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## UNIVERSITY OF WISCONSIN
Madison, Wisconsin 53706

### OCEANOGRAPHY PROGRAM

The graduate training program in oceanography is administered by an interdepartmental committee. The program is based on the premise that oceanography and limnology should be considered together as an integrated field requiring a broad base in fundamental disciplines plus specialization in the application of one particular discipline to the hydrosphere. Participating departments are Bacteriology, Botany, Civil Engineering (including Water Chemistry), Geology and Geophysics, Meteorology, and Zoology.

Each discipline with marine programs has its own complete laboratory facilities. A new meteorology research building to be completed in 1968 will have one floor (approx. 6,000 sq. ft.) devoted to oceanography. A new engineering research building will also have substantial space devoted to ocean engineering. Specific oceanographic facilities include the Laboratory of Limnology, Water Chemistry Laboratory, fixed and barge-borne micrometeorological towers, numerous small boats (30'), and a twin engined aircraft instrumented to make measurements of infrared radiation, air temperature, turbulence, albedo, and other meteorological parameters. A geophysical capability exists for making at-sea gravity and seismic measurements and airborne magnetic measurements.

Instructional Staff:

Department of Bacteriology

ELIZABETH F. McCOY, Ph.D., Professor
WILLIAM B. SARLES, Ph.D., Professor and
Chairman

Department of Botany

GRANT COTTAM, Ph.D., Professor
RICHARD I. EVANS, Ph.D., Associate
Professor
GERALD C. GERLOFF, Ph.D., Professor
and Director of Institute of Plant
Development
ORIE L. LOUCKS, Ph.D., Associate Professor
JONATHAN D. SAUER, Ph.D., Professor,
joint with Geography

Department of Civil Engineering

JOHN A. HOOPES, Ph.D., Assistant
Professor
ARNO T. LENZ, Ph.D., Professor
PETER L. MONKMEYER, Ph.D., Associate
Professor
GERARD A. ROHLICH, Ph.D., Professor
and Director of Water Resources Center
JAMES R. VILLEMONTE, Ph.D., Professor

Department of Civil Engineering - Water Chemistry

G. FRED LEE, Ph.D., Professor and
Director Water Chemistry Program
DEMETRIOS SPYRIDAKIS, Ph.D., Assistant
Professor

Department of Geology and Geophysics

DAVID L. CLARK, Ph.D., Associate
Professor
ROBERT H. DOTT, JR., Ph.D., Associate
Professor
ROBERT P. MEYER, Ph.D., Associate
Professor
J. ROBERT MOORE, Ph.D., Associate
Professor

Department of Meteorology

REID A. BRYSON, Ph.D., Professor and
Director of the Center for Climatic
Research
STEFAN L. HASTENRATH, Ph.D., Associate
Professor
HEINZ H. LETTAU, Ph.D., Professor
ROBERT A. RAGOTZKIE, Ph.D., Professor
and Chairman

Department of Zoology

LEMUEL A. FRASER, Ph.D., Professor
ARTHUR D. HASLER, Ph.D., Professor and
Director of Laboratory of Limnology
H. FRANCIS HENDERSON, Ph.D., Assistant
Professor
JOHN C. NEESS, Ph.D., Associate Professor

Degrees Offered:

Ph.D. in Oceanography and Limnology
Minor in Oceanography for Ph.D. in
in other fields

Courses Offered:

Department of Botany

Graduate Courses

Upper Division

330 ALGAE
Evans

Emphasis on the taxonomy and ecology of local freshwater forms.

450 PRINCIPLES OF PLANT ECOLOGY
Cottam, Loucks

Plants and plant communities in relation to their environment.

Graduate Courses

801-802 ADVANCED PLANT ECOLOGY
Loucks, Staff

Community Biology: survey of concepts in classification and study of plant communities, their structure and development. Experimental Ecology: energy relations, adaptations, and physiological ecology of plants and communities.

944 SEMINAR IN PLANT GEOGRAPHY
Sauer

950 SEMINAR IN PLANT ECOLOGY
Cottam, Loucks

## Department of Civil Engineering

### Graduate Courses

#### Upper Division

602 HYDRODYNAMICS
Monkmeyer, Hoopes

Equations of motion, continuity and energy in three dimensions using vector analysis; application of potential theory and complex variables to the flow of an ideal fluid; applications to engineering problems.

612 OPEN CHANNEL HYDRAULICS
Villemonte, Monkmeyer

Application of basic principles of fluid mechanics to flow in open channels; concepts of boundary layer theory; criteria for analysis of uniform, gradually varied, and rapidly varied flows; special design problems including applications of digital and analog computers.

621 HYDROLOGY
Lenz

Hydrology of the water cycle as related to air mass movement, precipitation, evaporation, stream flow, floods, infiltration, and groundwater including statistical hydrology; water supply applications of hydrology including studies of water demand, storage transportation, and groundwater development.

### Graduate Courses

863 FREE SURFACE FLOW
Monkmeyer, Hoopes

Free surface, gravity flow from mathematical viewpoint; theory of gravity waves using potential theory; unsteady open channel flow; flood routing; applications to design.

960 HYDRAULIC ENGINEERING AND FLUID MECHANICS SEMINAR
Villemonte, Monkmeyer, Hoopes

Theoretical and applied fluid mechanics, current research and literature.

## Department of Geology

#### Lower Division

130 SURVEY OF OCEANOGRAPHY
Moore

A survey of fundamental topics and contemporary problems in the science of the sea including scientific exploration, configuration of the ocean basins, properties of sea water, currents and circulation, sediments on the sea floor, economic resources of food, minerals, energy and water, and oceanographic factors bearing on modern social, commercial, legal, international, and exploitation problems of the world ocean.

### Graduate Courses

#### Upper Division

533 CHEMICAL ASPECTS OF SEDIMENTATION
Bowser

Processes and products of weathering and the chemistry and mineralogy of sediments.

535 PHYSICAL ASPECTS OF SEDIMENTATION
Dott

Textures, structures, transportation, and classification of clastic sediments.

537 GEOLOGICAL OCEANOGRAPHY
Moore

Introduction to shipboard operations, precision bathymetry, station navigation, distribution of major types of shelf and deep sea deposits, geological aspects of the oxygen minimum layer, principal oceanographic processes which influence the nature of the bottom, interpretation of hydrographic charts, and economic resources of the sea. Short boat trips will be taken to demonstrate the use of modern sampling devices.

538 RECENT MARINE SEDIMENTS
Moore

Composition and texture of modern ocean floor sediments, both clastic and carbonate, deposited on the continental shelf and in the deep-sea provinces of the world ocean, with emphasis on calcareous and siliceous oozes, marine lutites, halmeic deposits, shelf sands, reef sediments, and introduction to modern core analysis and data interpretation techniques.

671 MARINE GEOPHYSICS
Staff

History and techniques of marine exploration, propagation of sound in the ocean, gravity, magnetic, and heat flow observations, the ocean bottom and crustal structure, physical description of ocean water and currents, waves, history of the oceans and ocean basins.

### Graduate Courses

777 SEA FLOOR GEOLOGICAL PROCESSES
Moore

Principal geological - oceanographical processes operative at or near the sea floor and their influence on the composition, alteration, and dispersal of marine sediments. Emphasis on processes rather than compositional properties.

977 SEMINAR IN SEDIMENTATION AND GEOLOGICAL OCEANOGRAPHY
Dott, Moore

## Department of Meteorology

### Graduate Courses

#### Upper Division

403 MICROMETEOROLOGY
Lettau, Stearns

The roles of friction, radiation, convection, and evaporation in the physics of the layer of air near the ground.

460 INTRODUCTORY OCEANOGRAPHY
Ragotzkie

Survey of the oceans, with emphasis on the physical processes and the relation of ocean and atmosphere.

### Graduate Courses

774 OCEANOGRAPHIC TECHNIQUES
Ragotzkie

Introduction to techniques used in the study of the chemistry, geology and physics of the marine environment.

861 PROBLEMS OF VISCOUS FLOW
Lettau

Basic principles of viscous action, energy transformation and dissipation, boundary layer theory, natural motion generated by heat sources, effects of boundary rotation.

862 PROBLEMS OF TURBULENT FLOW
Lettau

Transition from laminar to turbulent flow, statistical parameters of turbulence, variance spectra, instability theories, transport mechanism, and energy transformation in turbulent flow.

960 SEMINAR: OCEANOGRAPHY

## Department of Water Chemistry

### Graduate Courses

#### Upper Division

642 WATER ANALYSIS
Staff

Lab methods and the interpretation of lab results for chemical analysis of water and waste water.

644 WATER CHEMISTRY
Lee

Chemistry of the elements in fresh and marine water; acidic and basic, precipitation, complexation, oxidation-reduction, sorption, and biochemical reactions in natural waters and water treatment processes.

645 WATER ANALYSIS-INTERMEDIATE
Lee, Spyridakis

Laboratory methods and interpretation of laboratory results for chemical analysis of water are discussed.

646 MARINE CHEMISTRY
Lee

Chemistry of elements in the oceans.

### Graduate Courses

770 ADVANCED WATER CHEMISTRY
Lee

Application of the theory of gas transfer flocculation, aerobic and anaerobic fermentations, adsorption, ion exchange, precipitation, chlorination, and sedimentation to the fresh and marine water environments and to water and wastewater treatment processes; lab exercises demonstrate natural water phenomena and water treatment processes.

771 ADVANCED TECHNIQUES OF WATER ANALYSIS
Lee

Methods of solute concentration, chromatographic separation and analysis, electrometric analytical methods of water analysis.

772 ADVANCED TECHNIQUES OF WATER ANALYSIS
Lee

Spectrophotometric, monometric, radiochemical, and continuous methods of water analysis.

773 ORGANIC WATER CHEMISTRY
Spyridakis

Composition and chemistry of organic compounds in natural waters and waste waters.

962 WATER CHEMISTRY SEMINAR
Lee

Current research and literature.

## Department of Zoology

### Graduate Courses

#### Upper Division

300 GENERAL INVERTEBRATE ZOOLOGY
Fraser

Structure, function, classification, and life histories of the major groups of invertebrates.

500 ECOLOGY
Neess

Relationships between living things and their environment including the dependence of one form of life on another, community organization, succession, and behavior of populations.

510 ECOLOGY OF FISHES
Hasler, Henderson

Physiological, ecological, and behavioral aspects in fishes; lab, field trips.

512 BIOLOGY OF THE PLANKTON
Staff

Pelagic organisms in lakes and oceans and the factors controlling their distribution and production; the course will cover planktonic plants and animals (e.g., algae, protozoa, rotifers, crustacea, and fish larvae) and the part they play in the economy of natural waters.

515 LIMNOLOGY - CONSERVATION OF AQUATIC RESOURCES
Hasler

General limnology, study of aquatic habitats and communities and their conservation.

## Graduate Courses

615 BIOLOGY OF AQUATIC POPULATIONS
Henderson

Structure and dynamics of aquatic animal populations, computer simulation studies. Laboratory and field exercises.

955 SEMINAR
Staff

Sections in various fields of zoological research.

Person to be contacted for further information:

Professor Robert A. Ragotzkie
Chairman
Interdepartmental Oceanography Committee
Science Hall
University of Wisconsin
Madison, Wisconsin 53706

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# CHAPTER 2

# CURRICULA IN OCEAN ENGINEERING

## THE CATHOLIC UNIVERSITY OF AMERICA
Washington, D. C. 20017

The Institute of Ocean Engineering sponsors interdisciplinary research in ocean engineering and underwater acoustics. Research is conducted at the University (Pangborn Hall - 88,000 square feet; annexes 42,000 square feet) and under a cooperative program at the U.S. Naval Research Laboratory and the U.S. Naval Ship Research and Development Center. Naval oceanographic ships are utilized for at sea research.

The Institute of Ocean Engineering also cooperates with several academic departments which offer programs in ocean engineering, acoustics, ship hydrodynamics, and water resources. The academic departments and their course offerings are listed below.

Instructional Staff:

- F.A. ANDREWS, Ph.D., Research Professor of Mechanics, Director, Institute of Ocean Engineering
- J.H. BALTRUKONIS, M.C.E., Professor of Mechanics, Chairman of Mechanics Department
- B.S. BROWZIN, D. Engr., D. Nat. Sc., D. Sc. (d'Etat), Professor of Civil Engineering
- R.W. DEUTSCH, Ph.D., Professor of Nuclear Science and Engineering
- A.J. FAVRET, D. Engr., Associate Professor of Electrical Engineering
- R. FORESTI, Jr., Ph.D., Associate Professor of Chemical Engineering, Chairman of Chemical Engineering Department
- J.J. GILHEANY, Ph.D., Associate Professor of Mechanics
- A.A. HUDIMAC, Ph.D., Associate Professor of Mechanics
- T.W. KAO, Ph.D., Assistant Professor of Space Science and Applied Physics
- E.B. MAGRAB, Ph.D., Assistant Professor of Mechanics
- G.E. McDUFFIE, Ph.D., Professor of Electrical Engineering
- L. MILLER, M.S., Instructor in Geography
- H.P. PAO, Ph.D., Assistant Professor of Space Science and Applied Physics
- D.F. PARSONS, M.S.C.E., Lecturer in Civil Engineering
- J.J. SCHULE, B.A., Lecturer in Mechanics
- B.L. SILVERSTEIN, D. Engr., Adjunct Professor of Mechanical Engineering
- A. THIRUVENGADAM, Ph.D., Lecturer in Mechanical Engineering
- R.J. URICK, M.S., Lecturer in Mechanics
- B.J. WITZIG, M.S., Lecturer in Civil Engineering
- L.T. CROOK, B.S.C.E., P.E., Lecturer in Civil Engineering
- E.J. MARTIN, Ph.D., Lecturer in Civil Engineering
- K.G. TOWER, M.S.C.E., Lecturer in Civil Engineering

Degrees Offered:

Master of Science in Engineering
(Acoustics, Ocean Engineering, Ship
Hydrodynamics, and Water Resources)
Doctor of Engineering or Doctor of
Philosophy (Acoustics and Ocean
Engineering)

Courses Offered:

Civil Engineering
Graduate Courses

Graduate courses are offered leading to the Doctorate in Transportation Engineering, Soil Mechanics, Structural Engineering, as well as the following courses which are applicable to the Master's Degree in Water Resources and Engineering and to Master's and Doctoral Degrees in Ocean Engineering:

### CE 581 WATERWAYS AND HARBOR ENGINEERING
Browzin

Planning and design of ports: analysis and design of wharves, piers, and harbor protective structures. Soil and rock conditions affecting the design of waterways and harbors. Interaction of structures and soil considering elastic and plastic properties of soils. Wind, tides, and waves, as major loads on marine structures. Breakwaters: type, shape, and material. Wharves and piers as statically indeterminate systems on elastic supports. Flexible bulkheads; analysis, design, and research. Anchors in soils. Stability of marine structures. Prerequisites: C.E. 382, C.E. 436 or equivalent.

### CE 583 INLAND WATERWAYS AND DAM ENGINEERING

Planning and design of inland waterways: analysis, and structural and hydraulic design of dams, navigation locks, canals; river bed improvements. Soil and rock conditions affecting the design of waterways and river structures. Planning of a river complex; dams, locks, and power stations. Existing typical river complexes. Gravity dams on soft soils and on rock. Buttress dams. Review of other dam types. Introduction to hydraulic and structural design of navigation locks. Principles of river bed improvement; review of cases. Design of canals. Prerequisites: C.E. 382, C.E. 436 or equivalent.

### CE 589 HYDROLOGY
Parsons

A study of the occurrence and physical effects of water on the earth and the relation of water to man's environment. Specifically: The hydrologic cycle, Precipitation, Development and use of stream flow data, Evapotranspiration, Occurrence of ground water, Hydrograph analysis, Routing, Frequency and duration analysis, and Forecasting. Prerequisites: M.E. 332.

**CE 590 HYDRAULICS OF OPEN CHANNELS**
Parsons

A broad treatment of open channel hydraulics to include: a review of basic principles; development, computations and design of channels for uniform flow; gradually varied flow; rapidly varied flow including spillways, the hydraulic jump, and nonprismatic channels; unsteady flow and flood routing; stream morphology. Prerequisite: Fluid Mechanics.

**CE 591 WATER RESOURCES ENGINEERING ECONOMICS**
Witzig

Economic analyses for engineering and management decisions for public water resource projects, including: values and social costs; equivalence; annual cost comparisons; capital recovery; funding; Federal, State, and local roles; national income and product alternatives; incremental analyses; sunk costs; intangibles; projecting and forecasting; economic growth and development; regional analyses; benefit evaluation, measurement, double counting; risk; uncertainty; probability; sampling; and confidence limits.

**CE 593-594 WATER RESOURCES PLANNING**
Crook

First semester: Criteria and principles of the engineering, economic, administrative, and legal aspects of public water resources planning, development and management.

Second semester: Application of criteria and procedures for formulating, evaluating, cost allocating, cost apportioning, and developing single-and multiple-purpose projects and basin plans for flood control, navigation, irrigation, water supply, water quality control, power, drainage, recreation, and fish and wildlife. Prerequisite or corequisite: C.E. 591.

**CE 595 CURRENT PROBLEMS IN WATER RESOURCES**
Crook

Examination of current problems in the field of water resources development, including problems of forecasting needs, conflicts among various purposes and interests, reservation and preservation of scarce sites, role of the civil engineer in relation to other planners, nonstructural solutions to flood problems, consequences of new legislation, and coordination of related programs, all developed through readings, discussion with program leaders in various government agencies, and research of solution for an outstanding problem.

**CE 596 PUBLIC WATER POLICIES AND ORGANIZATIONS**

Studies of methods and procedures by which public policies are formulated in the field of water resources, basic policies of most important agencies, and the types of organizations used (and proposed) for development of water resource plans and evaluation of their effectiveness and shortcomings.

**CE 597-598 WATER QUALITY MANAGEMENT AND ADVANCED WASTE TREATMENT**
Martin

Advanced study in the theoretical and applied aspects of analysis and management of advanced water and waste treatment processes of water quality control through system analysis of the entire environmental water shared system.

**CE 599 HYDRAULIC STRUCTURES**

**CE 600 PLANNING FOR HYDROELECTRIC POWER DEVELOPMENT**
Tower

Hydroelectric power resources; factors effecting potentials. Competitive sources of power. Forecasting future power market requirements. Adaptation of hydroelectric potential to the market and the power systems of which it will be a part. Operations of a power system including multiple-purpose storage projects.

**CE 601 COASTAL ENGINEERING**

**GEOG 714 COASTAL MORPHOLOGY**
Miller

Morphologic study of coastal areas and processes that develop shore lines and near-shore oceanographic features. Field trips in the Chesapeake Bay area. Prerequisite Geog. 511.

**GEOG 705 INTERPRETATION OF AERIAL PHOTOGRAPHS**

## Mechanical Engineering

Graduate courses are offered leading to the Doctorate in fluid mechanics, thermodynamics and heat transfer, and mechanical systems. The following courses are applicable to the Master's Degree in ship hydrodynamics and the Master's and Doctoral Degrees in ocean engineering:

**M.E. 551 THEORY OF SHIP RESISTANCE AND PROPULSION**
Silverstein

Components of resistance including viscous and wavemaking resistance; model test techniques; effect of hull geometry on resistance; bulbous bows; prediction of ship resistance; propeller theory; design and testing of propellers; nozzled propellers, supercavitating and ventilated propellers.

**M.E. 552 CAVITATION, SUPERCAVITATION AND CAVITATION DAMAGE**
Thiruvengadam

Cavitation inception; effects of cavitation; supercavitating flows involving drag of slender bodies and supercavitating hydrofoils; experimental facilities and techniques; mechanisms of cavitation of materials and liquids related to damage; protective methods.

M.E. 554 ADVANCED HYDRODYNAMICS
Silverstein

Free surface theory for potential flow including derivation of boundary conditions; linearization; solution using Green's function of Michel's integral; consequences of Michel theory; high and low Froude number asymptotic expansions; steady two-dimensional free surface problems using sources, doublets and vortices.

M.E. 555 THEORY OF SHIP MOTION
Silverstein

Simplified deterministic theory; added mass and damping; linear and non-linear rolling; ocean waves; coupled pitch and heave; forced motion in waves; anti-roll devices.

M.E. 556 STABILITY AND CONTROL OF SHIPS

Derivation of equations of motion of submerged towed and untowed bodies; evaluation of coefficients with geometry by theoretical and experimental techniques; establishment of stability criteria; linearized control theory; applications to marine vehicles.

Mechanics Department

Graduate courses are offered leading to the Doctorate in solid mechanics, biomechanics, and applied physics. The following courses are applicable to the Master's and Doctoral degrees in acoustics and ocean engineering:

MECH 546 VIBRATIONS AND ACOUSTICS LABORATORY
Staff

An instructional laboratory designed to teach fundamental experimental concepts in acoustics and vibrations; experiments covering the following topics: fundamentals of measurement, dynamics of point masses, dynamics of beams and plates, velocity of sound in air, absorption of sound, reciprocity calibration of a transducer, directivity index of simple sources, electromechanical analogy of a transducer, signal processing, photoelastic techniques in vibrations.

MECH 561 WAVES
Andrews

Elements of wave motions; progressive waves; waves subject to boundary conditions; harmonic analysis; waves in elastic media and the analogy to electromagnetic waves; waves in incompressible fluids.

MECH 563 PRINCIPLES OF UNDERWATER SOUND
Urick

Introduction and some fundamentals; the sonar equation and the sonar parameters; propagation in the sea; transmission loss; source level and directivity index; reverberation; ambient noise in the sea; radiated and self noise of ships, submarines and torpedoes; sound scattering by sonar targets; target strength; detection threshold; miscellaneous topics; applications and problem solving.

MECH 564 UNDERWATER SOUND PROPAGATION
Urick

Introduction and theoretical review; experimental methods for investigating sound propagation in the sea; velocity of sound in the sea water; acoustic oceanography; ray tracing in underwater sound; convergence zones; ducts in the sea; the mixed layer; the ocean sound channel; shallow water sound propagation; fluctuation of transmitted sound; reflections and scattering by the sea surface and the bottom.

MECH 566 FUNDAMENTALS OF SOUND
Andrews

Simple sound radiators; propagation in a circular tube; non-homogeneous waves in a tube; radiation and scattering by a cylinder and sphere; radiation by a plane piston.

MECH 572 PHYSICAL OCEANOGRAPHY
Gilheany

Physical and chemical properties of sea water; variation of properties in the ocean; thermodynamics of the ocean, instrumentation and observational techniques; the ocean masses, currents, waves and tides.

MECH 574 OCEAN WAVES
Schule

Presentation of the physical principles of hydrodynamics required to develop a modern treatment of ocean surface wind-waves theory. Emphasis on development of ocean wave spectrum models for application to wave forecasting.

MECH 761-762 THEORETICAL ACOUSTICS
Hudimac

Classical theories of acoustic propagation in solids and fluids; homogeneous and inhomogeneous (including layered) media; moving media; normal modes; Green's functions; ray theory; perturbation methods; scattering from bubbles and solid objects; radiation impedance and other interactions.

EE 528 ELECTROACOUSTIC DEVICES
Preisman

Treatment of mechanical systems that are capable of being represented by their electrical analogs, such as electrodynamic microphones, pickups and loudspeakers, piezoelectric projectors and pickups, as well as other problems such as automobile suspension systems; treatment of combination electrical-mechanical systems; analysis of transmission through and radiation from tubes and horns. Two hours of lecture-recitation per week. Prerequisites: Engr. 305, E.E. 421, E.E. 441.

### EE 561-562 RANDOM SIGNAL THEORY
Favret

Study of random processes by using random variables, probability distributions, time and ensemble averages, correlation functions and power spectra. Implications of sampling theory; optimum filtering and prediction; signal processing and simple decision theory. Three hours of lecture-recitation per week. Prerequisites: Math. 533 and 534, or Math. 570; prerequisite or corequisite: E.E. 521, 522.

### SSAP 735-736 GEOPHYSICAL FLUID MECHANICS
Pao and Kao

Equations of motion in rotating coordinate systems. Local Cartesian coordinates. Geosirophic, gradient and inertial flows. Kinematics of vorticity. Bjerkness Theorem. The dynamics of rotating and stratified fluids, including effect of compressibility. Taylor-Proudman Theorem. Boussinesq approximation. Wave motion and blocking. Flow concentration and jets. Ekman boundary layer. Vortex flow over a solid boundary. Thermal convection and Rayleigh instability. Stability of couette flow. Stability of heterogeneous shear flow. Interfacial wave generation mechanism. The wind-sea problem. Turbulence in a stratified medium. Analogy between hydromagnetic, rotating and stratified flows. Application to meteorology, oceanography and astrophysics. Prerequisite: SSAP. 534 or 542.

Person to be contacted for further information:

Dr. John J. Gilheany
Institute of Ocean Engineering
The Catholic University of America
Washington, D.C. 20017

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## FLORIDA ATLANTIC UNIVERSITY
Boca Raton, Florida 33432

### DEPARTMENT OF OCEAN ENGINEERING

The objective of the Department of Ocean Engineering is to provide a comprehensive, practical curriculum in science and engineering which will prepare the student to perform engineering tasks in the ocean medium and environment. This undergraduate course will lead to a Bachelor of Science degree in ocean engineering which will qualify the student for professional positions in oceanic industries, and for graduate study in marine science and technology. Florida Atlantic University, an upper division university will accept students who have successfully completed pre-engineering or pre-science courses at junior colleges or lower divisions of four-year universities.

Ocean engineering laboratories are being established in the Sanson Science Building in the summer of 1967; a 41' Hatteras boat, a Mobile Science Laboratory (Sea Van) used on ONR Research Ships of opportunity projects, and a shallow water submerged laboratory (Hydro-Lab) placed off the coast of Palm Beach, Florida constitute the specialized laboratory facilities of the Department's research and teaching programs.

Instructional Staff:

CHARLES R. STEPHAN, B. S., Department Chairman and Professor Ocean Engineering
RAYMOND F. McALLISTER, Ph.D., Professor of Oceanography
WILLIAM TESSIN, Ph.D., (ME) Associate Professor of Ocean Engineering
CHESTER L. WAKAMO, M.S., (ME), B. S. (EE) Associate Professor Ocean Engineering
JAMES B. DAVIDSON, M. S., (ME) Associate Professor Acoustics
JEFFREY S. TENNANT, M. S., (ME) Associate Professor of Ocean Engineering

Degrees Offered:

Bachelor of Science in Ocean Engineering

Courses Offered:

### OCEN 301 INTRODUCTION TO OCEANOGRAPHY

Survey course including: study of the history of oceanography; the origin of the ocean basins, the continents, and sea water; physical and chemical oceanography, marine biology, marine geology, meteorological oceanography, and Florida oceanography. A brief introduction to ocean engineering will be included. Prerequisite: none. Engineering majors may not offer this course for credit.

### OCEN 302 OCEANOGRAPHY I (Physical Oceanography)

The world ocean; its physical dimensions and characteristics; distribution of salinity, temperature and pressure in the sea; density and water mass distribution; waves, tides and currents; sound and electromagnetic radiation; heat budget of the oceans; sea-air interface studies, etc. This course stresses applications where pertinent. Prerequisites: Engineering major or permission of instructor.

### OCEN 303 OCEANOGRAPHY II (Chemical Oceanography)

Sea water; its chemical nature and the distribution of major and minor elements, gases and nutrients in the sea; salinity and chlorinity and their measurement; principal marine chemical processes; the carbonate cycle in the sea; geochemistry of sediments; problems in marine chemistry. Prerequisites: Engineering major or permission of instructor.

### OCEN 304 OCEANOGRAPHY III (Geological Oceanography)

The ocean boundaries and their geological characteristics; beaches and beach phenomena; the continental shelf slope and deep sea floor; marine sediments, their classification, origin and history; sediment analysis; processes active in formation, transportation and deposition of marine sediments; eustatic and local sea level changes; coral reefs; problems in marine geology. Prerequisites: Engineering major or permission of instructor.

### OCEN 305 OCEAN ENGINEERING LABORATORY

Ocean engineering and oceanographic demonstrations and practical problems. Navigation, positioning and survey systems, ocean engineering operations and techniques. Seamanship principles, practical work, and problems. Prerequisites: OCEN 302, 303. Corequisite: OCEN 304.

### OCEN 310 STRENGTH OF MATERIALS I

### OCEN 311 STRENGTH OF MATERIALS II

Concepts of stress and strain, Hoode's Law, deformations of elastic materials, torsion, bending, strain energy, elements of limit analysis, statically indeterminate elastic systems, Castigliano's Theorem, thin wall rings and shells, riveted and welded joints, columns and struts. Prerequisites: OCEN 351 (Statics).

### OCEN 320 ELEMENTS OF ELECTRICAL ENGINEERING I

Definitions and units, experimental laws and simple circuits, useful techniques of circuit analysis, network theory, introduction to electronics, vacuum tube and semiconductor devices, rectifier circuits, amplifiers and oscillators, wave shaping circuits, modulation, special topics and applications. Prerequisites: Math thru Integral Calculus College Physics with Calculus.

### OCEN 321 ELEMENTS OF ELECTRICAL ENGINEERING II

Forced and transient responses to deterministic inputs, sinusoidal steady-state response of circuits, magnetic fields and circuits, generation of voltages, electromagnetic forces and torque, transformers, electromechanical energy conversion, linear approximation of machine analysis. Prerequisites: OCEN 320, Differential Equations.

### OCEN 322 ELEMENTS OF ELECTRICAL ENGINEERING III

Complex frequency analysis, feedback theory and circuits, principles of automatic control, dynamic behavior of control systems, frequency-response methods, transfer functions and system stability, linear and non linear operation, analog and digital modes of operation, computation, and simulation techniques. Prerequisites: OCEN 321.

### OCEN 330 FLUID MECHANICS I

### OCEN 430 FLUID MECHANICS II

### OCEN 431 FLUID MECHANICS III

Physical properties of fluids, fluid statics and dynamics, potential flow, boundary layers in incompressible flow, dimensionless numbers and dynamic similarity, fluid flow, in pipes and open channels, dynamic drag, fluid measurements, forces on immersed bodies, turbomachines, cavitation, surface and internal gravity wave motion. Prerequisites: OCEN 352 Dynamics, OCEN 340 Thermodynamics I.

### OCEN 340 ENGINEERING THERMODYNAMICS I

Thermodynamic definitions, properties and state of pure substances, macroscopic thermodynamic processes and systems and cycles, work and heat, the first and second laws, entropy, availability, irreversibility, and efficiency. Prerequisites: Mathematics thru Differential Equations.

### OCEN 341 ENGINEERING THERMODYNAMICS II

Continuation of Engineering Thermodynamics I with applications to: ideal gases, mixtures of vapors and gases, reciprocating process machines, standard and actual power and refrigeration cycles, nozzles and blade passages, combustion. Prerequisites: OCEN 340.

### OCEN 351 STATICS

Forces and force systems and their external effects on bodies; principally, the condition of equilibrium. The techniques of vector mathematics are employed. Prerequisites: Mathematics thru Calculus.

### OCEN 352 DYNAMICS

Principles of dynamics, kinematics, kinetics of particles and rigid bodies including work and energy, impulse and momentum, periodic motion. The techniques of vector mathematics are employed. Prerequisites: OCEN 351 (Statics).

### OCEN 400 OCEAN ENGINEERING INTERNSHIP AND INDEPENDENT STUDY

A cooperative work-study summer program arranged with various ocean oriented companies, government agencies and laboratories for ocean engineering students who have successfully completed their junior year, including on-the-job ocean engineering training and instruction during summer employment. A comprehensive technical report will be written and graded on the summer work accomplished.

### OCEN 401 ENGINEERING MATERIALS I

OCEN 402 ENGINEERING MATERIALS II

Sources of metallic and non-metallic materials, structure and properties of metals, polymers, ceramics and composite materials, crystalline and non-crystalline phases, phase transformations, heat treatment of metals, elements of corrosion. Prerequisites: College Physics (with Calculus) College Chemistry.

OCEN 412 SHOCK AND VIBRATION

Equivalent springs, masses and driving systems, rigid-body dynamic analysis, steady-state response, phase-plane, normal modes, shock spectra, single degree and two degree of freedom systems, computer analysis of multi-degree of freedom systems, introduction to mechanical impedance methods, analysis of lumped and distributed parameter mechanical systems, dynamic behavior of a foundation-like structure, vibration isolation of non-rigid bodies, analysis of stochastic excited vibration systems. Prerequisistes: (Differential Equations) OCEN 423, OCEN 352, Statistics and Probability.

OCEN 420 UNDERWATER ACOUSTICS I

Fundamentals of acoustics, physical properties of acoustic waves in water, variation in sound velocity studies, introduction to wave acoustics and ray acoustics, solution of the wave equation, adiabatic and isothermal conditions, energy density, velocity, gradients, constant velocity-gradient method, ray equations and tracing, solution in terms of normal modes, boundary conditions and long-range propagation paths, some unsolved problems in connection with underwater acoustics. Prerequisites: Differential equations. OCEN 330. Corequisite: OCEN 423.

OCEN 421 UNDERWATER ACOUSTICS II

Oceanographic factors affecting sound conditions, ambient noise, echos, scattering and reverberation, intensity fluctuations, acoustic properties of wakes, experimental procedures, shallow-water and deep water transmission, reflectivity, attenuation, transmission of explosive sounds in the sea, introduction to seismics, basic transducer systems, active and passive sonar systems, direct listening methods and related hydrodynamic effects, fundamental factors in echo ranging. Applications in oceanography and marine geology. Prerequisite: OCEN 420.

OCEN 422 UNDERWATER ACOUSTICS III

Generation and detection of underwater sounds, special transducers, piezoelectric and magnetostrictive devices, directional characteristics, broadside arrays, thermal noise, calibration of transducers, reciprocity theorem, excitation of electro-acoustic sound projectors, mechanical design considerations, analysis of signal detection methods, signal detectability theory, measurements in the ocean as a problem in filter theory, recognition differential, special types of pulses, signal processing considerations. Prerequisite: OCEN 421.

OCEN 423 INSTRUMENTATION

Definition and classification of variables, measurement errors and statistical analysis, generalized performance characteristics of instruments, comparison measurements, physical measuring devices, transducers, operation amplifiers for measurement and control, manipulation, transmission and recording of data electronic switching, timing and digital counting systems, data processing techniques, indicators and recorders, telemetry systems. Prerequisites: OCEN 320-322 Differential equations, statistics and probability.

OCEN 430 FLUID MECHANICS II

OCEN 431 FLUID MECHANICS III

(See OCEN 330 for Course Description)

OCEN 432 UNDERWATER STRUCTURES

Introduction to theory of plates and shells, thick wall pressure vessels, instability; elements of buckling of plates, shells, and cylinders. Prerequisites: OCEN 310, 311 (Strength of Materials).

OCEN 440 HEAT TRANSFER

Elements of steady state heat transfer; thermal conduction, convection, and radiation; condensation and boiling heat transfer; thermal resistance; introduction to transient heat conduction. Prerequisites: OCEN 340, 341 (Engineering Thermodynamics); OCEN 330, 430,431 (Fluid Mechanics).

OCEN 460 OCEAN ENGINEERNG SEMINAR

Seminar sessions with invited leaders in the ocean engineering profession. Preparation and presentation of technical papers by students on ocean engineering topics and projects selected by student with consent of instructor.

Person to be contacted for further information:

Professor Charles R. Stephan
Chairman, Department of Ocean Engineering
Florida Atlantic University
Boca Raton, Florida 33432

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## UNIVERSITY OF MIAMI
Miami, Florida 33149

### INSTITUTE OF MARINE SCIENCES

### Division of Ocean Engineering

No undergraduate major is offered in ocean engineering. Preparation for graduate work and practical participation in the field is obtained by seeking the degree of Bachelor of Science in some area of engineering. The inclusion of undergraduate courses in introductory oceanography, marine biology and marine geology will be helpful to the student.

Instructional Staff:

JOHN H. CLOTWORTHY, B.E.E., Senior Research Engineer and Chairman of Division of Ocean Engineering.
KENNETH G. COMPTON, M.S., Assistant Professor of Marine Physical Science-Corrosion.
JOHN F. MICHEL, M.S., Research Associate and Assistant Chairman of Division of Ocean Engineering.
NORMAN L. WEINBERG, B.E.E., Associate Professor of Electrical Engineering.

Degrees Offered:

M.S. in Ocean Engineering.

Courses Offered:

#### Senior and Graduate Courses

531 OCEANOGRAPHIC MEASUREMENTS

Theory of measurements, requirements and restraints, transducers, oceanographic measurements, navigation and data processing. Lecture, 3 hours. Prerequisite: Mathematics 311, Physics 212 or permission of instructor.

535 INTRODUCTION TO UNDERWATER ACOUSTICS

Fundamentals of vibration, harmonic analysis, propagation of sound, acoustic concepts, plane and spherical waves, refraction, reflection, and boundary conditions. Introduction to ray tracing, normal mode theory, ambient noise, transducers, and hydrophone characteristics. Prerequisite: Mathematics 311, Physics 212.

541 MARINE CORROSION

The general principles of corrosion and its prevention stresses marine corrosion, atmospheric and underground, with respect to the severity of environment and susceptibility of materials. Rates of corrosion, selection of materials, protective coatings, cathodic protection and other mitigative measures. Lecture, 2 hours. Prerequisite: Permission of instructor.

#### Graduate Courses

607 PROBLEMS IN OCEAN ENGINEERING

This course introduces the engineer to the special problems and areas he will encounter when doing work in ocean engineering. Staff is drawn from government agencies, industry, and research laboratories of the universities, as well as from the University of Miami. This course will cover selected topics such as: manned and unmanned vehicles, deep sea moorings, anti-submarine warfare. Prerequisite: Physical Science 501 or permission of division chairman.

631 PRINCIPLES OF OCEAN ENGINEERING

Application of ocean environment to engineering design. Economic considerations, applied ocean hydrodynamics, interaction between the ocean and structures, measurement of environmental parameters, data transmission and processing, cables and connections, corrosion, fouling, systems engineering, underwater living and working, ocean construction procedures. Prerequisite: Physical Science 501 and permission of division chairman.

Person to be contacted for further information:

Edwin S. Iversen
Chairman, Division of Graduate Studies in Marine Sciences
University of Miami
Miami, Florida 33149

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## UNIVERSITY OF HAWAII
Honolulu, Hawaii 96822

### THE OCEAN ENGINEERING PROGRAM

Ocean engineering at the University of Hawaii is a relatively new program which cuts across departmental and college boundaries. It is defined as the application of science and technology to problems unique to the marine environment. Currently, ocean engineering at the University of Hawaii is a graduate program at the master's level, but graduate education and research of doctoral caliber are being conducted in advance of the formal establishment of the doctoral program, which should follow shortly.

To date the primary research emphasis in ocean engineering is related to shore line and harbor problems. The major research facility is the Look Laboratory of Oceanographic Engineering which was acquired from the U.S. Army Corps of Engineers in January, 1966. This laboratory conducted the Hilo Harbor Model Study and the Waikiki Beach Model Study, and is currently involved in studies related to the new Barber's Point Harbor and the effect of tsunamis on Oahu and its environs. It is the first structure of the Kewalo Oceanographic Research Center, and supports research activity that has direct bearing on many ocean-related problems occurring throughout the state of Hawaii.

This $400,000 facility is presently being enlarged with a $200,000 appropriation from the State, and a contemplated Federal matching fund grant from NSF. This expansion will result in the creation of a research facility which will have application to ocean-related problems extending to continental shelf depths.

Parallel activity is taking place in the development of mathematical models and in increasing the testing program in the sea, both by the University and through cooperative studies with local military and civilian ocean-related organizations. The goal is to achieve the following capability:

a. The physical simulation, for model study purposes, of pertinent aspects of the ocean environment from the shore line, through continental shelf depths, and into the deep ocean.

b. The development of mathematical models and laboratory analogies which will simulate various phases of the ocean environment.

c. In situ testing in the deep and shallow ocean environment.

Instructional Staff:

C.L. BRETSCHNEIDER, Ph.D. (Chairman) - Civil Engineering, Physical Oceanography
N. BURBANK, Sc.D. - Environmental Engineering
T.K. CHAMBERLAIN, Ph.D. - Geological Oceanography
R. GRACE, Ph.D. - Civil Engineering
G. W. GROVES, Ph.D. - Oceanography
J. M. JORDAAN, Jr., Ph.D. - Ocean Engineering
J. LARSEN-BADSE, Ph.D. - Materials Science
J.A. WILLIAMS, Ph.D. - Civil and Ocean Engineering, Hydromechanics

Degrees Offered:

The Master of Science in ocean engineering is an interdepartmental graduate program contributed to by the Departments of Oceanography, Civil Engineering, Electrical Engineering, and Mechanical Engineering. Intended candidates for the Master of Science in ocean engineering must present a B.S. in civil, chemical, electrical, or mechanical engineering, or the equivalent. Plan A (thesis program) is recommended but Plan B (non-thesis) may be permitted. Choice of plan must be made before 14 credits of graduate work applicable to the degree have been completed. Foreign language is not required.

Plan A requires a minimum total of 30 credit hours, including 24 credit hours of course work and 6 credit hours of thesis research. Six credit hours of course work may be taken outside the College of Engineering and the Department of Oceanography. At least 8 credits must be in courses numbered 600-799.

Plan B requires 30 credits of course work. At least 6 credit hours shall be taken outside the College of Engineering and the Department of Oceanography. At least 8 credits must be in engineering courses. Two graduate seminars in engineering or oceanography are required. A minimum of 18 credits must be in courses numbered 600-799.

Required Courses:

620 PHYSICAL OCEANOGRAPHY (3) I

Introduction to physics of the oceans; physical properties; heat budgets; energy transformation; interaction with boundaries; dynamic equilibrium; waves, currents, and tides; water masses and circulation patterns of the seas. Pre: Math 114 or 143 or consent of instructor.

625 OCEAN ENGINEERING (3) I

Principles of ocean engineering as an application of the knowledge of fluid mechanics and oceanography to engineering problems encountered in coastal and marine environments. Pre: consent of instructor.

Elective Courses:

Six credits of approved courses may be selected from physics, mathematics, chemistry, or geosciences. Additional courses normally will be selected from the following list:

Civil Engineering

621 ADVANCED FLUID MECHANICS I (3)

622 ADVANCED FLUID MECHANICS II (3)

626 COASTAL AND HARBOR ENGINEERING (3)

635 ENVIRONMENTAL AND SANITARY ENGINEERING CHEMISTRY (4)

636 ENVIRONMENTAL AND SANITARY ENGINEERING MICROBIOLOGY (4)

651 ADVANCED SOIL MECHANICS (3)

671 THEORY OF ELASTICITY (3)

674 THEORY OF ELASTIC STABILITY (3)

675 THEORY OF VIBRATIONS (3)

676 STRUCTURAL DYNAMICS (3)

678 PLATES (3)

679 THEORY OF THIN SHELLS (3)

681 ADVANCED INDETERMINATE STRUCTURES (3)

682 NUMERICAL METHODS OF STRESS ANALYSIS (3)

683 ADVANCED REINFORCED CONCRETE DESIGN (3)

### Electrical Engineering

601-602 ELECTROMAGNETIC THEORY AND APPLICATIONS (3-3)

603 ACTIVE NETWORK ANALYSIS

631 ADVANCED ELECTRONIC INSTRUMENTATION (3)

651 ADVANCED FEEDBACK CONTROL SYSTEMS (3)

652 OPTIMIZATION TECHNIQUES IN CONTROL SYSTEMS (3)

655 SAMPLED-DATA CONTROL SYSTEMS (3)

661 THEORY AND DESIGN OF DIGITAL MACHINES (3)

663 INFORMATION THEORY (3)

665 SIGNALS AND RANDOM NOISE (3)

### Mechanical Engineering

601 ADVANCED ENGINEERING THERMODYNAMICS (3)

605-606 HEAT TRANSFER (3-3)

631 CORROSION (3)

### Oceanography

622 GEOLOGICAL OCEANOGRAPHY (3)

623 CHEMICAL OCEANOGRAPHY (2)

632 LITTORAL GEOLOGICAL PROCESSES (3)

640 ADVANCED PHYSICAL OCEANOGRAPHY (3)

642 RECENT MARINE SEDIMENTS (3)

660 OCEAN WAVE THEORY (3)

661 TIDES (3)

Person to be contacted for further information:

Dr. Charles L. Bretschneider
Department of Oceanography
University of Hawaii
Honolulu, Hawaii 96822

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## MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Cambridge, Massachusetts 02137

The Ocean Engineering Graduate Program at MIT, administered by the Department of Naval Architecture and Marine Engineering, emphasizes the principles governing the conceptual formulation, design, construction and operation of vehicles and stationary floating structures and their integration into systems for the exploration and utilization of ocean resources, the conduct of oceanographic research, and the recovery of objects from the ocean floor. As such, it treats special surface vehicles, submerged vehicles, stationary floating platforms and structures, support of ocean mining and oil drilling, engineering support for ocean fisheries, engineering aspects of ocean explorations, engineering aspects of oceanographical research, and support for ocean bottom stations.

The ocean engineering degrees offered by the Department of Naval Architecture and Marine Engineering require a program of study built around specified and elective subjects dealing with many engineering topics, a few of which include: Design synthesis, Sonar systems, Energy sources for ocean engineering, Ocean vehicle hydromechanics, and Ocean vehicles strength analysis. The program will draw on existing capabilities in the Department of Naval Architecture and Marine Engineering as well as in other departments at MIT.

The Department of Naval Architecture and Marine Engineering maintains a ship model towing tank with the capability of generating random surface waves and a variable pressure circulating water tunnel. Both have unusual flexibility in application to ocean engineering research. An acoustics and vibration laboratory and a structural mechanics laboratory also are available in the Department. Laboratory facilities of all other departments at MIT are available whenever they can provide support for research pertinent to ocean engineering.

The ocean engineering program will also take advantage of the joint degree program in oceanography between Woods Hole Oceanographic Institute and MIT. Close cooperation with Woods Hole Oceanographic Institute in ocean engineering is assured; as an initial step, participation of MIT ocean engineering graduate students in Woods Hole Oceanographic Institute projects can be arranged.

Instructional Staff:

### Department of Naval Architecture and Marine Engineering

ALFRED ADOLF HEINRICH KEIL, Dr.Rer.Nat., Head of Department and Professor of Naval Architecture
MARTIN AARON ABKOWITZ, Ph.D., Professor of Naval Architecture
JOHN HARVEY EVANS, B.Eng., Professor of Naval Architecture
PATRICK LEEHEY, Ph.D., Professor of Naval Architecture
PHILIP MANDEL, B.S., Professor of Naval Architecture
ERNST GABRIEL FRANKEL, Mar.Mech.E., Associate Professor of Marine Engineering
JUSTIN ELLIOT KERWIN, Ph.D., Associate Professor of Naval Architecture
JOHN NICHOLAS NEWMAN, Sc.D., Associate Professor of Naval Architecture
MIGUEL CHAPERO JUNGER, Sc.D., Lecturer (Visiting)

### Department of Civil Engineering

ARTHUR THOMAS IPPEN, Ph.D., Professor of Civil Engineering
FREDERICK JEROME McGARRY A.B., S.M., Professor of Civil Engineering
RUSSEL CAMERON JONES, Ph.D., Associate Professor of Civil Engineering
ZIAD MALEK ELIAS, Sc.D., Assistant Professor of Civil Engineering

## Department of Mechanical Engineering

ASCHER HERMAN SHAPIRO, Sc.D., Head of Department and Professor of Mechanical Engineering
ROBERT WELLESLEY MANN, Sc.D., Professor of Mechanical Engineering
STEPHEN HARRY CRANDALL, Ph.D., Professor of Mechanical Engineering
HENRY MARTYN PAYNTER, Sc.D., Professor of Mechanical Engineering
S. WILLIAM GOUSE, JR., Sc.D., Associate Professor of Mechanical Engineering
PHILIP GRAHAM HILL, Sc.D., Associate Professor of Mechanical Engineering

## Department of Metallurgy

HERBERT HENRY UHLIG, Ph.D., Professor of Metallurgy

## Department of Electrical Engineering

YUK-WING LEE, Sc.D., Professor of Electrical Engineering
WILLIAM McCONWAY SIEBERT, Sc.D., Professor of Electrical Engineering

## Department of Aeronautics and Astronautics

JOHN DUGUNDJI, Sc.D., Associate Professor of Aeronautics and Astronautics

## Department of Political Science

NORMAN JUDSON PADELFORD, Ph.D., LL.D., Professor of Political Science

Degrees Offered:

At the graduate level, the degrees offered are: S.M. in Ocean Engineering, Professional degree of Ocean Engineering, and Ph.D. and Sc.D. in Ocean Engineering.

Although MIT does not offer an undergraduate degree in ocean engineering, students completing a S.B. in naval architecture and marine engineering, in mechanical engineering, in civil engineering, or in aeronautics and astronautics, among others, may readily transfer to the Ocean Engineering Graduate Program. The transition will be greatly facilitated if appropriate electives are chosen during undergraduate studies.

Courses Offered:

## Department of Naval Architecture and Marine Engineering

### Undergraduate Subjects

13.00 PRINCIPLES OF NAVAL ARCHITECTURE
Kerwin, Abkowitz, Mandel

Dynamics and hydrodynamics applied to resistance and propulsion of ships: wave hydrodynamics; propellers and interaction effects between propeller and ship; equations of motion and stability indices for maneuvering of ships and submarines; definitive maneuvers; hydrodynamics of control surfaces; ship motions in regular and irregular seas. Laboratory exercises in ship model towing tank and propeller tunnel. Prerequisite: 1.05 or 1.612 or 2.201T.

13.63 HYDROSPACE VEHICLES AND THEIR USE
Mandel, Keil

Development of performance criteria common to all vehicle types. Physical principles governing the performance of submarines, surface ships, hydrofoils, planing craft and surface effect ships. Comparison to aircraft. Impact of technological advances in power plants, structural materials and thrusters on the performance of hydrospace vehicles. Economic criteria governing the role of these vehicles in peaceful pursuits. Performance of these vehicles in a wartime environment. Prerequisite: None.

### Graduate Subjects

13.04 HYDROFOIL AND PROPELLER THEORY (A)
Kerwin

Development of the theory of hydrofoils in two- and three-dimensional non-cavitating flow following classical aerodynamic theory for incompressible flow, including application of conformal mapping and thin airfoil, lifting-line, and lifting-surface theory. Topics in propeller theory, including propeller lifting-line and lifting-surface theory and applications to the design of homogeneous flow and wake-adapted propellers. Introduction to unsteady and supercavitating hydrofoil theory. Prerequisite: 18.06.

13.05 CAVITY FLOWS (A)
Leehey

Linear and nonlinear cavity flow models at zero and at finite cavitation numbers. Two-dimensional steady and unsteady linearized cavity flows about wedges and hydrofoils. Three dimensional steady cavity flows. Effects of gravity and boundary surfaces. Compressibility considerations. Theories of planing and water entry. Comparisons of theory with experimental results. Identification of current research problems. Several mathematical approaches introduced to emphasize the method of Muskhelishvili for two-dimensional problems. Prerequisite: 1.631 or 2.25 or 13.04 or 16.02 or 18.60.

13.07 FREE SURFACE HYDRODYNAMICS (A)
Newman

Water wave phenomena pertinent to problems in naval architecture and ocean engineering. Generation, propagation and diffraction of plane progressive waves. Exciting and restoring forces on floating and submerged bodies. Wave resistance of ships. Wave effects in shallow water and in stratified fluids. Prerequisite: 18.06.

### 13.17 OCEAN ENGINEERING STRUCTURES (A)

Evans

Seminar on the structural design of semi-submerged mobile drilling platforms, bottom supported towers, submarine vehicles, bottom habitations and stayed structures. Brief treatment of the evaluation of towing, mooring, wave, jacking and bottom suction loads needed for the structural design of these vehicles and platforms. Configuration optimization of pressure chamber structures, moorings, buoy systems and anchoring devices. Emphasis on selection of materials. Prerequisite: 2.01.

### 13.18 SHIP STRUCTURAL DYNAMICS (A)

Keil

Dynamic response of ship structural configurations in the elastic and plastic range. Elastic response of ship structures to wave generated loads, slamming pressures and propeller or machinery generated forces; extension to plastic deformation and ultimate failure. Derivation of loads associated with explosive effects both under water and in air and the elastic and plastic response of ship structures and shipboard installations to these explosive loads. Prerequisite: 2.03 or 13.19.

### 13.42 DESIGN OF A WATERBORNE VEHICLE (A)

Mandel

Determination of performance criteria for a waterborne vehicle or platform based on an arbitrary set of system mission requirements established by the student in consultation with instructor. Preparation of the preliminary design of the vehicle or the floating platform fulfilling the selected performance criteria. Participation by several students in a single project encouraged. Prerequisite: 13.41.

### 13.50 COMPUTER APPROACHES TO PROBLEMS IN NAVAL ARCHITECTURE AND MARINE ENGINEERING

Kerwin

Steps required in the development of useable computer programs for the solution of engineering problems including problem definition, numerical analysis, program organization, FORTRAN IV programming, M.I.T. Computation Center operating procedures, development of program tests, debugging and program documentation. Assigned projects and lectures based on realistic problems in naval architecture and marine engineering selected to illustrate many of the advantages and difficulties encountered in computer applications. (Primarily for seniors and graduate students in Naval Architecture and Marine Engineering others admitted by permission of the instructor.) Prerequisite: 18.05.

### 13.61 DECISION PROCESSES IN SHIP OPERATION AND CONSTRUCTION (A)

Frankel

Development of techniques which optimize decisions in the face of uncertainty on a long-term basis. Analysis of legal, financial, assurance, political, trade, labor, and administrative factors influencing the shipping venture. Routing and scheduling. Bayesian statistics and decision theory. Information flow and system response prediction. Critical path and networks. PERT II. Integration of transportation systems. Prerequisite: 6.28J or 13.60 or 18.10; 13.00; 13.10; 13.20; 14.01.

### 13.92T POLITICS, LAW AND THE OCEANIC REALM

Padelford

Study of the views of the principal nations on possession and use of oceanic space. Examination of national and international politics, law and agreements relating to jurisdiction, Continental Shelf, fisheries, navigation, mining, sub-surface occupancy, deep submergence, and man-in-the-ocean; problems for national and international regulation; role of the U.N. and other agencies. Prerequisite: None.

### 13.95 HYDROACOUSTICS (A)

Leehey

Topics in underwater acoustics important to modern naval architecture and marine engineering. Physics of water; mechanism of cavitation; cavitation noise. Radiation of sound by various types of sources. Transmission of sound in the ocean. Fundamentals of active and passive sonars. Vibrations in marine structures and machinery. Engineering applications to ship and submarine noise control. Prerequisite: 2.03 or 13.19; 18.06.

### 13.97 ACOUSTICS OF SUBMERGED STRUCTURES (A)

Junger

Analysis of concepts relevant to acoustic performance of submerged structures; radiations of extended plates, transmissions of noise along hull plating, self noise, dynamics of submerged shells and associated sound radiations, acoustic transients. Model and full-size experimental techniques and selected applications to ship noise problems. Prerequisite: 2.03 & 18.06; or 13.19 & 18.06; or 13.95.

### 13.98 STABILITY AND MOTION CONTROL OF OCEAN VEHICLES (A)

Abkowitz

Interaction between surface waves and surface and near surface free-floating bodies. Principles of design of control systems to reduce wave excited, six degree of freedom body motions to acceptable specified levels at zero speed and at finite ahead speed. Vehicle and platform design principles leading to motion reduction. Applications to ships, catamarans, oil drilling platforms and flip-ships. Precise motion control of submerged vehicles at very low speeds.

Note: 13.03 will be helpful as additional preparation. Prerequisite: 13.00, 13.10, 18.05; or 13.03.

## Department of Civil Engineering

### Undergraduate Subjects

None.

### Graduate Subjects

1.42 STRUCTURAL MATERIALS (A)
Jones

Mechanical behavior of important materials in civil engineering structures. Principles relating composition and structure to such behavior. Emphasis upon basic factors to facilitate understanding and use of new materials and combinations. Elastic, plastic, viscoelastic, and other time-dependent types of deformation. Influence of defects and imperfections. Consideration of creep and fracture phenomena, adhesion and corrosion, composites and multi-phase systems. Reference to present and anticipated materials. Laboratory primarily concerned with structure-composition-mechanical property interactions. Prerequisite: 1.02.

1.472 COMPOSITE MATERIALS (A)
McGary

Concepts underlying formation characteristics and behavior of plastics-based composites such as fiberglass laminates, structural sandwiches, plywood, and load-bearing adhesive joints. Typical components such as metals, glass, synthetic and natural adhesives, plastics, foams, wood, paper, fabrics, and rubber. Correlation between adhesion principles and physical behavior. Methods of design, analysis, fabrication, and testing. Discussion of failure mechanisms of chemical, electrical, and mechanical types. Laboratory on individual project basis investigating problems related to current research. Prerequisite: 1.42.

1.584 ANALYSIS OF SHELL STRUCTURES (A)
Elias

General derivation of the governing equation for the technical theory of thin shells. Specialization for various types of shells such as spherical, cylindrical, etc. Discussion of the assumptions, limitations, and solution techniques for the membrane theory. Consideration of parametric expansion procedures for the bending theory of shells of revolution with application to cylindrical and spherical shells. Discussion of shallow shell theory with application to various shells such as hyperbolic paraboloids, etc. Prerequisite: 1.561.

1.65 FREE SURFACE FLOW (A)
Ippen

Steady and unsteady flow in open channels, boundary resistance and boundary layer problems, surface curves, channel transitions and controls, standing waves, hydraulic jump, surges and waves. Secondary flow, stratification, internal currents due to density variation, turbulent diffusion phenomena. Prerequisite: 1.05.

1.69 WAVES AND COASTAL PROCESSES (A)
Ippen

Hydrodynamics of waves for deep and shallow water, wave generation refraction, energy transmission and dissipation; coastal phenomena, harbor and breakwater problems. Analysis of tides and tidal currents; saltwater-freshwater interaction and diffusion in estuaries; erosion and shoaling in tidal waters. Prerequisite: 1.65 or 1.681.

## Department of Mechanical Engineering

### Undergraduate Subjects

2.731 ENGINEERING DESIGN
Mann

Instruction and experience in the integrated aspects of creative design and design analysis. In the context of an overall system theme, individual students define and design interrelated projects, with original concepts and thorough engineering analysis equally stressed; lectures devoted to background information, competitive approaches, and pertinent disciplinary and theoretical material; frequent student presentations and critiques culminate in formal "professional" presentation to experts from industry and government. (Those students wishing to do so and who can arrange mutually satisfactory projects with their respective faculty counselors, may undertake a single project to satisfy the requirements both of 2.731 and of the second term of 2.671, experimental engineering.) Prerequisite: 2.022, 2.30, 2.861.

### Graduate Subjects

2.061 RANDOM VIBRATION (A)
Crandall

Introduction to mathematical description of stochastic processes. Fourier transforms, power spectral density and autocorrelation functions. Analysis of response of mechanical systems to random excitation. Properties of narrow band Gaussian distributions. Application to vibration problems in missiles and jet airplanes involving wide-band random excitation. Fatigue damage under random loading. Prerequisite: 2.03, 18.05.

2.062 WAVE PROPAGATION (A)
Crandall

Wave kinematics, phase and group velocities, energy propagation. Examples of elastic, acoustic, electromagnetic, and magnetohydrodynamic waves. Ray theory versus wave theory. Transmission, absorption, refraction, diffraction, and scattering of waves. Method of stationary phase. Selected topics from the following: propagation through periodic structures, propagation through layered media, propagation through inhomogeneous, moving or random media, nonlinear waves. Prerequisite: 18.05, 18.06.

### 2.065 FLOW NOISE (A)

Leehey

Lighthill's theory of sound radiated from free turbulence. Kirchhoff's formula for the retarded potential Source, doublet and quadrupole radiation. Curle's theory of the influence of solid boundaries. Sound from a turbulent boundary layer: wall pressure spectrum, correlation area, Mach number effect, reflection principle for an infinite rigid wall. Radiation from a flexible wall. Theory of vortex sound: edge tone, aeolian tone, feedback effect of resonators. Comparison of theory with experimental results. Prerequisite: 1.632 or 2.063 or 2.25 or 13.95 or 16.041 or 18.60.

### 2.25 ADVANCED FLUID MECHANICS (A)

Shapiro

Survey of principal concepts and methods of fluid dynamics. Statics. Continuity, momentum, and energy relations for continuous fluids. Kinematics of fluid motion. Governing equations for motion of non-viscous fluid. Vorticity and circulation. Kelvin's theorem. Helmholtz' vorticity equation and vortex laws. Crocco's theorem. Stream function. Potential flow. Conformal transformation. Theory of lift. Navier-Stokes equation for motion of real fluids and applications. Boundary layer theory. Turbulence. Drag. Wave propagation. Applications to fluid machinery, propulsion systems, process industries, and aerodynamics. Prerequisite: 2.201T, 18.05.

## Department of Metallurgy

### Undergraduate Subjects

None.

### Graduate Subjects

### 3.54T CORROSION (A)

Uhlig

Quantitative application of electrochemical principles to corrosion reactions. Effect of metallurgical factors; atmospheric, soil, or aqueous environments; exidation and tarnish; stray currents; cathodic and anodic protection; metallic, inorganic and organic coatings; inhibitors, treatment of water and steam systems; [illegible]ion of materials. Prerequisite: [illegible].

## Department of Electrical Engineering

### Undergraduate Subjects

None.

### Graduate Subjects

### 6.57 RANDOM SIGNALS AND LINEAR SYSTEMS (A)

Siebert

Combination of a review of methods for the representation and analysis of linear systems with an elementary introduction to probability theory and the problems of characterizing random signals and noise. Specifically intended for first-year graduate students entering from other schools and planning to pursue further studies in the area of statistical communication theory. Topics in the area of random signals including: fundamentals of probability theory, random variables, distributions, averages, characteristic functions, transformation of variables, limit theorems, ensembles and random processes, correlation functions and spectra, elementary detection and decision problems. Topics in the area of linear systems including: convolution and super-position integral, complex frequency and system functions, Fourier-Laplace integral representations for signals. Examples selected to illustrate important concepts and problems in modern communication. Prerequisite: 6.02, 18.05.

### 6.571 STATISTICAL THEORY OF COMMUNICATION (A)

Lee

Messages and noise as stationary random processes. Elementary probability theory, statistical characteristics of messages and noise, particularly correlation functions and spectra. Measurement of correlation functions. Detection of signals in the presence of noise by correlation. Determination of impulse response of linear systems by correlation. Theory of the statistical optimum filter, predictor, compensator, differentiator, and general linear system operator. Synthesis of optimum linear systems by normal and orthogonal functions. Prerequisite: 6.05.

## Department of Aeronautics and Astronautics

### Undergraduate Subjects

None.

### Graduate Subjects

### 16.94 DYNAMICS OF STRUCTURES (A)

Dugundji

Brief review of Hamilton's Principle, Lagrange's Equations, natural mode shapes and frequencies, and the normal-mode equations of motion. Elastic response of complex structures to gust, blast, and other transient loads. Prediction of large dynamic responses and permanent deformations of shell structures by elastic-plastic and rigid-plastic analysis. Propagation of elastic, elastic-plastic, and extremely intense stress waves in solids. Spall fracture. Hypervelocity impacts. Prerequisite: 16.91.

Person to be contacted for further information:

Dr. A. H. Keil
Head, Department of Naval Architecture
and Marine Engineering
Room 5-226
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

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## UNIVERSITY OF NEW HAMPSHIRE
Durham, New Hampshire 03824

## OCEAN-ORIENTED ENGINEERING

### The Engineering Design and Analysis Laboratory

Study and research in the application of engineering to ocean exploration and exploitation is centered in the Engineering Design and Analysis Laboratory (EDAL), which is sponsored by all of the engineering departments. Faculty and students in engineering join in engineering projects aimed at solving real problems in oceanography and carry their developments through actual sea trials whenever possible. The Laboratory maintains cordial but informal relationships with several oceanographic institutions, both private and government operated, which permits staff and students to have open ocean experience as well as the use of model tank testing facilities.

The Laboratory occupies 2000 ft. of floor space in Kingsbury Hall in the College of Technology, including a pressure test facility, an instrumentation laboratory and a student shop. Students and staff have access to all of the University facilities such as the Computation Center, the Electron Microscope, the State Engineering Test Station equipment for materials analysis and testing, and a fully equipped machine shop.

Instructional Staff:

- G. H. SAVAGE, Engr., Professor, Mechanical Engineering, Director EDAL
- O. T. ZIMMERMAN, Ph.D., Professor and Chairman, Chemical Engineering
- R. W. CORELL, Ph.D., Professor and Chairman, Mechanical Engineering
- A. E. WINN, M.S., Professor and Chairman, Electrical Engineering
- R. SKUTT, Ph.D., Associate Professor, Electrical Engineering
- V. AZZI, Ph.D. Engr., Associate Professor, Mechanical Engineering
- D. MELVIN, M.S.A., Associate Professor, Electrical Engineering
- E. E. ALLMENDINGER, M.S. (Naval Arch), Associate Professor, Mechanical Engineering
- H. GEHRHARDT, Ph.D., Assistant Professor, Chemical Engineering
- F. GLANZ, Ph.D., Assistant Professor, Electrical Engineering
- J. BRONZINO, M.S., Assistant Professor, Electrical Engineering
- L. KLOTZ, M.CE., Assistant Professor, Civil Engineering
- D. NORRIS, Ph.D., Associate Professor, Mechanical Engineering
- F. BLANCHARD, M.S., Associate Professor, Electrical Engineering
- J. MURDOCK, Ph.D., Associate Professor, Electrical Engineering
- H. STOLWORTHY, B.S., Professor, Mechanical Engineering

Degrees Offered:

Master of Science in Chemical, Electrical, or Mechanical Engineering.

Courses Offered:

### Undergraduate Subjects

M.E. 671 NAVAL ARCHITECTURE I
Allmendinger

Introduction to naval architecture; geometry and hull form delineation; hydrostatic characteristics of floating and submerged bodies; introduction to ship strength; computer applications to naval architectural problems.

M.E.-E.E. 695, 696 ENGINEERING PROJECTS

A special study for seniors involving investigation of problems of current staff interest. All projects in this course are currently focused upon ocean-oriented engineering problems. Students work in project groups of 2 to 4 persons under the supervision of an interested faculty member. All projects are funded by the University and are not subject to the demands of outside sponsorship.

### Undergraduate (seniors) & Graduate Subjects

M.E. 772 NAVAL ARCHITECTURE II
Allmendinger

Hydrodynamic resistances of surface ships and submerged bodies; model testing theory; powering and propellers; use of "Standard Series" tests; introduction to ship motion, control and steering; concepts of ship design; computer application to problems.

Tech. 780 ENGINEERING ANALYSIS

Using the case method of instruction, this course offers accelerated experience in engineering synthesis and inventive design. Some of the cases are taken from ocean-oriented engineering project experience. For graduate students and seniors in engineering.

Graduate Subjects

Chem.E., E.E., M.E. 899 MASTER'S THESIS

All engineering design projects of the Engineering Design and Analysis Laboratory are structured to include graduate students who wish to take their Master's Thesis from an ongoing project oriented toward ocean problems. Current efforts are in hyperbaric systems for diver-scientists, oceanographic telmetry, control systems for dynamic oceanographic instrumentation, buoy technology, manned submersible vehicles, bioengineering concerned with marine vertebrates.

Office to be contacted for further information:

The Office of the Marine Affairs
Coordinator
Kingsbury Hall
University of New Hampshire
Durham, New Hampshire 03824

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## UNIVERSITY OF RHODE ISLAND
Kingston, Rhode Island 02881

### COLLEGE OF ENGINEERING

### Department of Ocean Engineering

The shore facilities and ship facilities of the Graduate School of Oceanography are available to ocean engineering faculty and graduate students. In addition, the College of Engineering laboratories include a well-equipped soils and sediments laboratory, an underwater acoustics laboratory in a new building, a sub-critical reactor, many wave and model tanks in the several engineering buildings. Nearby Navy and industrial laboratories have made much of their facilities available for cooperative research work.

Instructional Staff:

F. H. MIDDLETON, Dr.Eng., Chairman and Professor
F. M. WHITE, Ph.D., Professor
G. A. BROWN, Sc.D., Professor
R. F. HILL, Ph.D., Professor
H. SCHENCK, JR., M.S., Professor
C. D. NASH, Ph.D., Professor
R. B. DOWDELL, Ph.D., Associate Professor
V. A. NACCI, M.S., Associate Professor
R. S. HAAS, M.S., Associate Professor
K. H. MAIRS, Met.E., Associate Professor
V. C. ROSE, Ph.D., Assistant Professor
J. STANISLAO, M.S., Assistant Professor
G. RODERICK, Ph.D., Assistant Professor

Degrees Offered:

Master of Science in Ocean Engineering
Doctor of Philosophy in Ocean Engineering

Courses Offered:

Many graduate engineering courses in the classic departments are available to ocean engineering majors and applicable to their programs of study. In addition to these, the following ocean engineering courses are offered.

OE 134 (ChE 134) CORROSION AND CORROSION CONTROL
Mairs

Chemical nature of metals, electrochemical nature of corrosion. Types of corrosion, influence of environment, methods of corrosion control, behavior of engineering materials, all with special emphasis on the ocean environment.

OE 201, 202 OCEAN ENGINEERING SEMINAR
Staff

Seminar discussions including presentation of papers based on research or literature survey. Most presentations by invited authorities from the University and elsewhere.

OE 203,204 OCEAN ENGINEERING PRINCIPLES
Staff

Emphasizes special ocean applications of classical engineering principles. Electrical, industrial, and mechanical engineering in semester I; chemical and civil engineering in semester II. Students proficient in particular field assigned advanced problems for that period.

OE 210 ENGINEERING OCEAN MECHANICS
White

Applied concepts in ocean flow processes; waves due to gravity, wind, and layered media; large and small scale turbulence; prediction of flow instability; wave forces on structures.

OE 231 INTRODUCTION TO THE ANALYSIS OF OCEANOGRAPHIC DATA
Staff

Design of oceanic experiments to determine spatial and temporal sampling rates, precision, accuracy, signal-to-noise ratios, etc. Description of typical ocean data collection and analysis systems. Development of relevant analysis techniques such as statistical functions and correlation theory.

OE 287 SUBMARINE SOIL MECHANICS
Nacci

Soil mechanics principles as applied to submarine slope stability, heaving, sinkage and anchorage problems with emphasis on effective stress principle and selection of shear strength of marine sediments.

OE 291, 292 SPECIAL PROBLEMS

Staff

Advanced work, under the supervision of a member of the staff and arranged to suit the individual requirements of the student.

OE 321 UNDERWATER ACOUSTICS I

Middleton

Wave equations, stress-strain relations, energy, pressure, and particle velocity. Ray theory, normal modes, refraction, reflection, layered media, scattering, with particular emphasis on sound propagation in the ocean. Acoustic properties of the sea, properties of solids.

OE 322 UNDERWATER ACOUSTICS II

Middleton

Transducers, radiators and receivers, directivity (array structures), equivalent circuits, efficiency; piezoelectricity, magnetostriction, sonar principles, measurements and calibration, detection and signal processing.

OE 351, 352 ADVANCED DESIGN

Brown

Advanced course coordinating engineering principles and economics in the design of complete ocean systems. Problems investigated individually with the guidance of one or more instructors.

OE 391,392 SPECIAL PROBLEMS

Staff

Advanced work under supervision of a member of the staff and arranged to suit the individual requirements of the student. (Lecture or laboratory according to nature of problem).

Person to be contacted for further information:

F. H. Middleton, Chairman
Ocean Engineering Department
College of Engineering
University of Rhode Island
Kingston, Rhode Island 02881

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# CHAPTER 3

# CURRICULA IN MARINE TECHNOLOGY

## SUFFOLK COUNTY COMMUNITY COLLEGE

Seldon, Long Island, New York 11101

The marine technology program at Suffolk County Community College is unique. Believed to be the only program of its kind in the nation, it offers new promise to the Long Island fish, shellfish and related industries that dot the shorelines of Long Island Sound and the Great South Bay.

Through the application of practical knowledge, the marine technology program promises new insight into the problems that confront shellfish cultivation, plant sanitation, and the problems associated with insuring a continuous supply of marine raw materials such as fish, shellfish and seaweed.

The fundamental goal of the program is to provide qualified high school graduates with two years of coordinated technical and general education courses at the college level in order to enable them to function as technicians in marine and allied industries. A graduate of this program receives an Associate in Applied Science Degree. and is prepared to assume the duties of a marine technician.

Instructional Staff:

C. DOUGLAS HARDY, M.S., Assistant Professor
JOHN A. BLACK, B.A., Instructor
WALTER L. SMITH, M.S., Associate Professor, Course Head - Marine Technology
CARL KIRCHNER, Ph.D., Professor, Head - Department of Science and Mathematics
HAROLD F. UDELL, B.S., M.Sc., M.S., Adjunct Assistant Professor
FRANK E. MARTIN, B.S., M.S. Ed, M.S., Associate Professor, Head - Department of Physical Science

Degrees Offered:

Associate in Applied Science

Courses Offered:

### MR11 COMMERCIAL FISHING TECHNIQUES

A study of the operation of all types of equipment used in the Mid-Atlantic and North Atlantic for taking fish, shellfish, and crustacea. Field trips will be made to augment the lecture.

### CH25-26 TECHNICAL CHEMISTRY

Basic chemical theory and practical experience in use of the various instruments used in marine chemistry.

### MR21 NAVIGATION

A study of the utilization of the sextant, octant, magnetic and gyro compasses, and other related instruments. Included will be navigational laws, courtesies, and map reading. Prerequisite: Math 5.

### MR25 ELEMENTS OF OCEANOGRAPHY

An introduction to the chemical and physical processes that compose the marine environment. Field analysis of samples, as well as laboratory analysis will be made, using pH meters, spectrophotometers, polarographs, and chromatographic apparatus (3 hours lecture, 3 hours laboratory) Prerequisite: Chem.9. Laboratory fee: $5.

### MR30 MARINE VERTEBRATES

A study of the fish of the northeastern area of the United States. Emphasis will be placed on physiology and ecology. (3 hours lecture, 2 hours laboratory) Prerequisite: Chem. 9. Laboratory fee: $5.

### MR35 PLANT SANITATION

A study of the techniques instituted in food processing to insure quality and sanitary conditions. A review of the laws governing handling, processing, storing, and distributing marine products will be made. ( 2 hours lecture, 3 hours laboratory) Prerequisite: MR12. Laboratory fee: $5.

### MR40 COMMERCIAL MARINE PRODUCTS

A study of products and by-products of marine organisms such as seaweed, fish, and shellfish. The laboratory will be devoted to methods of extraction and analysis. (2 hours lecture, 2 hours laboratory) Prerequisites: Chem. 9 and Bio. 13. Laboratory fee: $5.

### MR45 ELEMENTS OF MARINE ECOLOGY

An introduction to the interrelationships of marine organisms based on the effects of the physical, chemical, and biological, environment. Field work will stress sampling and measuring techniques. (3 hours lecture, 3 hours laboratory) Prerequisites: MR25 and Bio. 13. Laboratory fee: $5.

### MR50 SHELLFISH

A study of the physiology and anatomy of clams, oysters, scallops, and other mollusca. Emphasis will be placed on techniques of culturing and growing the various shellfish. (3 hours lecture, 3 hours laboratory) Corequisite: MR45. Laboratory fee: $5.

### MR55 ELEMENTS OF APPLIED MARINE ELECTRONICS

A study of various electronic instruments used in the fishing industry such as fish finders, depth finders, and navigation equipment. Emphasis will be placed on field use and maintenance. (2 hours lecture, 3 hours laboratory) Prerequisite: MR21. Laboratory fee: $5.

Person to be contacted for further information:

Director of Admissions
Suffolk County Community College
Seldon, Long Island
New York 11101

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## CAPE FEAR TECHNICAL INSTITUTE
Wilmington, North Carolina 28401

The marine technology program at the Cape Fear Technical Institute at Wilmington, designed to train men in the necessary skills for the various marine industries, provides for both technical studies in the classroom and practical experience at sea.

Operations at sea, in the Institute's own training ship, include practical seamanship, navigation, fishing operations, and necessary experiments, collection, and processing of the data in connection with marine biology and oceanography.

The School Ship ADVANCE II which has a length of 185 feet, a beam 33 feet, and a draft of 11 feet, carries a twenty-six foot motor launch for oceanographic and hydrographic work and a Coast Guard approved whale boat for rescue training. The vessel's range is 2,500 miles at 15 knots. Accommodations for up to 70 students and instructors, in addition to the crew, are available. A small machine shop, pipe fitters shop, and electricians shop are also aboard.

Navigational equipment on the ship includes: 2 radar sets, 48 mile range; 3 PPI scopes; 4 Loran systems including A&C; 1 automatic direction finder; 1 portable direction finder; 2 marine radio-telephones; 4 radio receivers; 1 sub-signal sounding machine 200 fathoms maximum depth, (300 fathoms white line recorder); 1 master gyro system with repeater peloruses.

Biological and fishing instruments and equipment used aboard the vessel include a number of trawls, seines, gill nets, plankton net, and dredges. Aboard ship, there is a biological laboratory for dissection, classification, and pickling of marine specimens; 2 brine tanks for freezing, chilling, and preservation of live specimens; a freezer for preservation of fish; and 2 double sectioned fish pens for icing of fish.

Oceanographic instruments and equipment on board the vessel include: 1 4 ton boom for heavy dredging; 2 BT winches, 600 feet cable each; 2 BT booms, adjustable; bathythermographs, acoustic current meters; current meters; oceanographic chemical laboratory for determination of salinity, oxygen, etc; oceanographic sedimentation laboratory; separate office for processing of oceanographic data; 37' cabin cruiser with depth recorder for shallow water work; two 26' launches for inshore work; several small boats for inshore specimen collecting; and a biological laboratory with refrigeration facilities.

Facilities at the CFTI consist of three well equipped laboratories for marine biology, chemistry, and physics and classroom area for instruction and demonstrations.

Instructional Staff:

ARTHUR W. JORDAN, Capt. School Ship ADVANCE II and Coordinator of Marine Technology Department, Instructor in Fishing Operations and Oceanography
ROGER H. AVERETTE, B.S., M.A., Ed. Instructor in Physics; Oceanography; Chemistry and Biology
WALTER A. ARSENEAULT, B.M.S., First Mate on School Ship, ADVANCE II and instructor in mathematics; Navigation and Seamanship, and Cartography
EMMETT J. GOSSEN, Chief Engineer School Ship, ADVANCE II and Instructor in Internal Combustion Engines; Marine Diesel Engines; Marine Auxiliary Equipment, and Shipfitting and Maintenance
BRIAN T. SULLIVAN, B.S., Second Mate on School Ship, ADVANCE II
ROBERT H. WILLIAMS, First Engineer on School Ship, ADVANCE II and instructor in engines

Degrees Offered:

Associate in Applied Science in Marine Technology

Courses Offered:

All courses offered in this program are under the Marine Technology Department.

### 101 TECHNICAL ENGLISH

Arseneault

Designed to aid the student in the improvement of self-expression in grammar. The approach is functional with emphasis on grammar, diction, sentence structure, punctuation, and spelling. Intended to stimulate students in applying the basic principles of English grammar in their day-to-day situations in industry and social life. Prerequisite: none.

### 102 TECHNICAL ENGLISH
Arseneault

Designed to aid the student in the improvement of self-expression in business and technical composition. Emphasis is on the sentence, paragraph and whole composition. Prerequisite: T-ENG 101.

### 103 TECHNICAL ENGLISH
Arseneault

The fundamentals of English are utilized as a background for the organization and techniques of modern report writing. Exercises in developing typical reports, using writing techniques and graphic devices are completed by the students. Practical application in the preparation of a full-length report is required of each student at the end of the term. This report must have to do with something in his chosen curriculum.

### 204 TECHNICAL ENGLISH
Arseneault

A study of basic concepts and principles of oral communications to enable the student to communicate with others. Emphasis is placed on the speaker's attitude, improving diction, voice and the application of particular techniques of theory to correct speaking habits and to produce effective oral presentation. Particular attention given to conducting meetings, conferences, and interviews.

### 101 TECHNICAL MATH
Arseneault

The real number system is developed as an extension of natural numbers. Number systems of various bases are introduced. Fundamental algebraic operations, the rectangular coordinate system, as well as fundamental trigonometric concepts and operations are introduced. The application of these principles to practical problems is stressed.

### 102 TECHNICAL MATH
Arseneault

A continuation of T-MAT 101. Advanced algebraic and trigonometric topics including quadratics, logarithms, determinants, progressions, the binomial expansion, complex numbers, solution of oblique triangles and graphs of the trigonometric functions are studied in depth.

### 103 TECHNICAL MATH
Arseneault

The fundamental concepts of analytical geometry, differential and integral calculus are introduced. Topics included are graphing techniques, geometric and algebraic interpretation of the derivative, differentials, rate of change, the integral and basic integration techniques. Applications of these concepts to practical situations are stressed.

### 101 TECHNICAL PHYSICS
Averette

A fundamental course covering several basic principles of physics. The divisions included are solids and their characteristics, liquids at rest and in motion, gas laws and applications. Laboratory experiments and specialized problems dealing with these topics are part of this course.

### 102 TECHNICAL PHYSICS
Averette

Major areas covered in this course are work, energy, and power. Instruction include such topics as statics, forces, center of gravity and dynamics. Units of measurement and their applications are a vital part of this course. A practical approach is used in teaching students the use of essential mathematical formulas.

### 103 TECHNICAL PHYSICS
Averette

Basic theories of electricity, types of electricity, methods of production, and transmission and transforming of electricity. Electron theory, electricity by chemical action, electricity by friction, electricity by magnetism, induction voltage, amperage, resistance, horsepower, wattage, and transformers are major parts of the course.

### Marine Science 301 NAVIGATION & SEAMANSHIP
Arseneault

Theory of navigation with a comprehensive study of the compass, compass error and its applications, various types of charts, plotting, piloting, navigation aids, buoys, lights, rules of the road, basic electronic navigation, Mercator and Great Circle sailing. Theory and practical application of shipboard procedures and seamanship.

### Marine Science 302 NAVIGATION & SEAMANSHIP
Arseneault

Practical problems in piloting including danger angles, soundings and effects of tides and currents. An introduction to celestial navigation covering topics, such as celestial equator system of coordinates, navigational triangle, lines of position, observed altitudes, and adjusting the compass. Laboratory exercises and experience will be given on aids to navigation including radar, radio direction finders, sonar echo ranging, depth recorders, gyro compass, etc. Shipboard procedures and practical seamanship will be stressed.

### Marine Science 303 NAVIGATION & SEAMANSHIP
Arseneault

Advanced theory and practice involving celestial navigation, elementary meteorology, storm tracking, winds, air pressure, and weather instruments. Laboratory exercises in navigation problems with additional work assigned in shipboard procedures, sanitation, and practical seamanship.

### Marine Science 304 CARTOGRAPHY
Arseneault

The techniques of producing boat sheets and plotting sheets for use in navigation and oceanography. Students will develop and produce various charts utilizing gnomonic, Mercator, Great Circle, anthographic and topographical projections. Laboratory exercises will be assigned in the use of the maneuvering board involving problems of navigation.

### Marine Science 307 OCEANOGRAPHY
Averette

The operation and maintenance of oceanographic instruments used in compiling data on sonic sounding, current velocity and direction, meteorological observations, depth and temperature conversion, swell observations, and movements of water masses. Laboratory exercises will be assigned in the development of oceanographic graphs and profiles.

### Marine Science 308 OCEANOGRAPHY
Averette

A comprehensive study of the methods and maintenance of equipment and various mechanisms used in the collecting of soil samples from the ocean bottom. Identification and measurement of the various types of soils, sediments, rocks, and other inorganic and organic materials found at the bottom of the ocean. A complete study of the bathymetry of the oceans and the methods of recording bathymetric data.

### Marine Science 311 FISHING OPERATIONS
Jordan

A study of the many types of devices and nets involved in the capture, transportation, and preservation of marine food animals. Laboratory exercises, lectures, and demonstrations will include schematics and rigging of the otter trawl. Fabrication of bottom dredges, construction of fish traps; long lining for swordfish and tuna. Students will be given an introduction to the fishfinder, yankee trawling and the manufacture and use of various types of fishing buoys.

### Marine Science 312 FISHING OPERATIONS
Jordan

A study of the techniques of capturing porgies, herring, mullet, tuna, shrimps, and menhaden. Field trips will be used to demonstrate modern methods employed in the bailing and pumping of the catch at sea and at the plant. A portion of this course will be devoted to the sport fishing industry and will include a study of the equipment as well as the methods and procedures used in the location, capture, and preservation of animals pertinent to the industry.

### Mechanics 317 SHIPFITTING & MAINTENANCE
Gossen

A practical course in the safe and proper use of machine and hand tools necessary to properly maintain the ship. Theory and practice will cover such topics as welding, burning, maintaining repair logs and records, preservation and maintenance of hull and machinery, ship plans and blueprints, rigging, booms, topping lifts, and ground tackle. Safety in operation will be stressed throughout this course.

### Mechanics 318 MARINE AUXILIARY EQUIPMENT
Gossen

A comprehensive study of marine auxiliary equipment, such as pumps, winches, compressors, generators, anchor windless, electrical steering apparatus, etc. Laboratory and shop practices in the repair and operation of ship's mechanical devices, engine room and generator room logs and records, and preventative maintenance procedures on all equipment.

### PM 301 INTERNAL COMBUSTION ENGINES
Gossen

The principles of operation of 2-cycle and 4-cycle internal combustion marine engines. Testing of engine performance, servicing and maintenance of pistons, valves, cams, camshafts, fuel and exhaust systems, cooling systems, proper lubrication, and methods of testing, diagnosing, and repairing. Emphasis will be given maintenance and preservation of marine engines.

### PM 302 MARINE DIESEL ENGINES
Gossen

Basic marine diesel principles and components, their applications and relationships. Fundamental principles involved in transformation of heat energy to mechanical energy. Theory of fuels, exhaust systems, injectors, pumps, combustion and pre-combustion chambers, and air induction systems. Laboratory practices will be directed to the proper maintenance, operation, and safety factors of the marine diesel engine.

CHEM 301 CHEMISTRY
Averette

Study of the physical and chemical properties of substances; chemical changes; elements, compounds, gases, chemical combination; weights and measurements; theory of metals; acids, bases, salts, solvents, solutions, and emulsions. In addition, study of carbohydrates; electrochemistry, electrolytes, and electrolysis in their application of chemistry to industry.

CHEM 306 MARINE CHEMISTRY
Averette

An introduction to the techniques and equipment used in the chemical analysis of seawater samples, temperature and depth calculation, obtaining bottom sediment samples, processing and coding methods in recording chemical oceanographic data. A study of the "bloom" growths of plankton and the effect these growths produce in the chemical composition of ocean water.

Biology 301 MARINE BIOLOGY
Averette

An introduction to the food chain with special emphasis on single-celled plants, animals and the invertebrates; grouping of animals; animal relationships; marine animal habitats; growth rates; variation and succession. A study of animal relationships and the effect of these relationships on fish population. Laboratory and observations of marine animals in aquaria. Analyses of ocean minerals with an introduction to bathymetry.

Biology 302 MARINE BIOLOGY
Averette

A study of the life and distribution of pelagic fish and bottom living fish with emphasis on the problem of over-fishing. Additional study will be given in marine animal identification as well as fish tagging methods with an introduction to fish farming and controlled raising of fish as a profitable business. The study of commercially valuable crustacea and mollusca.

AHR 306 MARINE REFRIGERATION
Gossen

A basic study of essential refrigeration terminology; laws of refrigeration; heat and methods of transfer; the compression system; compressors, refrigerants and their characteristics; pressure--temperature relationships; conventional, hermetic, and absorption system of refrigeration; and special shipboard refrigeration systems.

TYPING AND CALCULATOR PRACTICE
Averette

GENERAL SHIP MAINTENANCE
Jordan

Persons to be contacted for further information:

Capt. Arthur W. Jordan
Coordinator Marine Technology
Department
Cape Fear Technical Institute
411 North Front Street
Wilmington, North Carolina 28401

or

Mr. Clarence E. Dodgens
Director of Student Personnel
Cape Fear Technical Institute
411 North Front Street
Wilmington, North Carolina 28401

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## SOUTHERN MAINE VOCATIONAL TECHNICAL INSTITUTE
South Portland, Maine 04106

### DEPARTMENT OF MARINE TECHNOLOGY

This program is designed to produce skilled men for various types of involvement in marine industries. Regular oceanographic stations are maintained by students with the aid of special oceanographic equipment. Specific data is obtained for shipboard and onshore observations in accordance with methods prescribed by the United States Navy Oceanographic Data Processing Center in Washington, D. C. Laboratory work includes salinity and oxygen determination by titration. Related laboratory work includes the construction of various graphs, plots and profiles from the data recorded by station observers on the oceanographic log sheets. Students are educated in the laboratory and field to identify many species of plant and animal which are important to man.

The onshore facilities consist of a marine industrial engineering building, a deck shop and a marine biology laboratory building.

Docking facilities are maintained to accommodate the AQUALAB (nautical school ship) and the Smithsonian Institution oceanographic vessel, PHYKOS. Approximately 40 days per school year are spent at sea aboard these training vessels, providing for practical ship operation and the development of technical skills.

Instructional Staff:

GEORGE W. HUPPER, Department Chairman and Instructor, Deck and Seamanship
EDWARD L. FOSS, M.S., Instructor, Marine Biology and Oceanography
ROBERT C. SOUCY, B.S., Instructor, Diesel Engineering
RICHARD P. ARLANDER, B.S., Instructor, Marine Engineering
CHARLES M. HALL, B.S., Instructor, Deck and Seamanship

**Degrees Offered:**

None (Diploma).

Students may specialize in any of the following fields: marine diesel engineering, deck and seamanship, marine laboratory assistance, marine biology and geological oceanography.

**Courses Offered:**

Undergraduate Courses

161. NAVIGATION I

Hall

Introduction to navigation with a comprehensive study of the history of navigation, basic definitions, charts, nautical publications, navigational instruments for dead reckoning and piloting, gyro and magnetic compasses and visual aids to navigation.

162. NAVIGATION II

Hall

The practical application of dead reckoning and piloting, tides and currents, Rules of the Road, Laws of the Nautical Road, Pilot Rules, electronic aids to navigation including radio direction finder, radar, Loran, recording fathometers and fish-finders, other hyperbolic systems.

163. NAVIGATION III

Hupper

Practical chart work, the sailings, introduction to advanced navigational publications, introduction to celestial navigation, the sextant, navigational astronomy, time and time-keeping instruments, and the nautical and air almanacs.

164. NAVIGATION IV

Hupper

Practical use of the sextant, application of the celestial line of position, solution by publications H.O. 214, 218, and 249. Compass error by azimuth, identification of celestial bodies, latitude sights and the complete practice of navigation at sea.

165. MARINE ENGINEERING I

Arlander

DIESELS: General description and construction of diesel engines, principles of operation, frames, cylinders, cylinder head, running gear, bearings, flywheels, valve gear. AUXILIARIES: piping, pipe fittings, tubing, valves, packing materials, gasket materials, pipe covering, reciprocating pumps, centrifugal pumps. ELECTRICITY: basic shipboard electricity, batteries, circuits.

166. MARINE ENGINEERING II

Arlander

DIESELS: fuel injection, governors, fuels and combustion, fuel systems, lubrication and lubricants. AUXILIARIES: gear pumps, jet pumps, blowers, heat exchanges, principles of distilling plans. ELECTRICITY: electromagnetism, principles of electric generators.

167. MARINE ENGINEERING III

Soucy

DIESELS: cooling systems, air intake systems, exhaust systems, starting and reversing methods, vibration and balancing, engine installation, operating a diesel engine. AUXILIARIES: refrigeration principles and equipment, compressed air systems, compressors. ELECTRICITY: maintenance of shipboard electrical equipment.

168. MARINE ENGINEERING IV

Soucy

DIESELS: engine performance, rating and testing, records, repairs, overhauling, special repairs and salvaging. AUXILIARIES: oil purifiers, control instruments, steering gear, windlasses, winches and capstans, marine heating systems. ELECTRICITY: operation and maintenance of shipboard electrical equipment, electric meters and test equipment. ENGINEERING SAFETY: fire prevention, fire-fighting equipment, respiratory equipment and emergency equipment, basic damage control, U.S. Coast Guard rules and regulations pertaining to marine engineering.

169. MARINE BIOLOGY I

Foss

This subject deals in the study of paleontology, ocean life versus terrestial life, laboratory observations and experiments, classification, evolution, physiological features of marine fauna, marine ecology and marine plants.

170. MARINE BIOLOGY II

Foss

Marine invertebrates, laboratory observations, field trips and studies.

171. MARINE BIOLOGY III

Foss

Marine invertebrates, plankton, benthon, nekton excluding fish, neuston and advanced laboratory observations and experiments.

172. MARINE BIOLOGY IV

Foss

Shell fish, fish and fisheries, other vertebrates, economics, laboratory and field study, theory and practical use of commercial fishing equipment.

173. SEAMANSHIP I

Hall

Classification of ships and ship construction, primary damage control, introduction to stability, helmsman's duties, steering, propulsion, navigational instruments, small boats, small boat construction, communications, watches at sea and in port, duties of a lookout watch, introduction to vessel maintenance, preparation of wooden and steel surfaces, painting, messman's duties, preparation of food at sea.

174. SEAMANSHIP II

Hall

Ground tackle, anchoring, mooring, cargo [illegible], cargo handling, equipment, classification and maintenance of rope fibre, synthetic and wire rope, marlinspike seamanship, knots, splices, mooring lines.

175. SEAMANSHIP III

Hupper

Ship handling at sea, emergency drills including man overboard, fire, fire and rescue, collision, abandon ship, sea anchors, storm oil, and ship handling around docks and other ships.

176. SEAMANSHIP IV

Hupper

Tugs and towboats, advanced towing and salvage, advanced damage control, advanced stability, dry-docking, ship's sanitation, vermine control, food sanitation, quarantine inspections, Rules and Regulations for Merchant Vessels, U.S. Coast Guard Inspections of vessels and small boats, Rules and Regulations for licensing and Certification of Merchant Marine Personnel.

177. OCEANOGRAPHY I

Foss

Introduction to oceanographic observations, oceanographic equipment and use, oceanographic station procedure, drawing oceanographic graphs, plots and profiles, use of biological collecting equipment, oceanographic log sheets procedure.

178. OCEANOGRAPHY II

Foss

Introduction to the chemistry laboratory and water analysis, data recording, data processing and interpretation, H.O. 607 procedure.

179. OCEANOGRAPHY III

Foss

Laboratory analysis, interpretation of data, compiling reports, maintaining oceanographic stations and their records, new equipment, physical oceanographic theory.

180. OCEANOGRAPHY IV

Foss

The study of winds, meteorology, air pressures, weather instruments, laboratory and field problems.

Person to be contacted for further information:

Mr. George W. Hupper, Chairman
Department of Marine Technology
Southern Maine Vocational Technical Institute
Fort Road
South Portland, Maine 04106

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# ALPHABETICAL FACULTY LIST

Abbott, Donald P. - Stanford U.
Abbott, Isabella A. - Stanford U.
Abkowitz, Martin A. - Mass. Inst. of Tech.
Adler, Cyrus - Long Island U.
Allen, George H. - Humboldt State C.
Allen, Kenneth W. - U. of Maine
Allen, Mary B. - U. of Alaska
Allen, William V. - Humboldt State C.
Allison, Edwin C. - San Diego State C.
Allmendinger, E. E. - U. of New Hampshire
Almodovar, Luis R. - U. of Puerto Rico
Alsop, Leonard E. - Columbia U.
Amstutz, David E. - Graduate School, USDA
Anderson, George C. - U. of Washington
Anderson, John - Cornell U.
Anderson, Orson L. - Columbia U.
Anderson, R. E. - U. of New Hampshire
Andrews, F. A. - Catholic U. of America
Andrews, Jay D. - Virginia Institute of Marine Science
Angelovic, Joseph W. - North Carolina State U.
Arking, Albert - New York U.
Arlander, Richard P. - Southern Maine Voc. Tech. Inst.
Arnal, Robert E. - San Jose State C.
Arseneault, Walter A. - Cape Fear Tech. Inst.
Arthur, Robert S. - Scripps Inst. of Ocean.
Averette, Robert H. - Cape Fear Tech. Inst.
Ayers, John C. - U. of Michigan
Azzi, V. - U. of New Hampshire
Baalen, C. Van - U. of Texas
Bader, Richard G. - U. of Hawaii
Bailey, J. R. - Duke U.
Bailey, W. Robert A. - U. of Delaware
Bailey, Robert S. - Virginia Inst. of Marine Science
Bakus, Gerald J. - U. of Southern California
Oregon Inst. of Marine Biology
Baltrukonis, J. H. - Catholic U. of America
Bandy, Orville L. - U. of Southern California
Banse, Karl - U. of Washington
Barber, Saul B. - Lehigh U.
Barkley, Richard A. - U. of Hawaii
Barlow, John P. - Cornell U.
Barnes, Clifford A. - U. of Washington
Barnhart, Roger A. - U. of Georgia
Barsdate, Robert J. - U. of Alaska
Barton, J. D., Jr. - Long Island U.
Baum, Werner A. - New York U.
Bayer, Frederic M. - U. of Miami
Be, Allan W. H. - Columbia U.
Beardsley, George F. - Oregon State U.
Behrens, E. W. - U. of Texas
Bennett, Lee C. - U. of Washington
Bennett, Sidney A. - U. of Delaware
Berkebile, C. A. - Long Island U.
Berner, Leo, Jr. - Texas A&M U.
Berry, Richard W. - San Diego State C.
Betz, Robert F. - Illinois Teachers C. Chicago North
Biehler, Shawn - Mass. Inst. of Tech.
Billings, W. D. - Duke U.
Birch, Francis - Harvard U.
Black, John A. - Suffolk County Community C.
Black, Robert E. L. - Virginia Inst. of Marine Science
Blake, Donald F. - Walla Walla C.
Blanchard, F. - U. of New Hampshire
Blinks, Lawrence R. - Stanford U.
Bloom, Arthur L. - Cornell U.
Bodvarsson, Gunnar - Oregon State U.
Boje, Rolt - U. of Washington
Bookhout, C. G. - Duke U.
Boord, Robert L. - U. of Delaware
Bonatti, Enrico - U. of Miami
Borns, Harold W. - U. of Maine
Borror, A. C. - U. of New Hampshire
Bothner, W. A. - U. of New Hampshire
Bouma, A. H. - Texas A&M U.
Bramlette, Milton N. - Scripps Inst. of Ocean.
Brauer, Ralph W. - U. of North Carolina
Brehmer, Morris L. - Virginia Inst. of Marine Science
Bretschneider, C. L. - U. of Hawaii
Brice, Arthur T. - U. of the Pacific
Briles, G. H. - Long Island U.
Brock, Vernon E. - U. of Hawaii
Brody, Marcia - City U. of New York
Broecker, Wallace S. - Columbia U.
Broida, Saul - U. of Miami
Brookbank, John W. - U. of Florida
Bronzino, J. - U. of New Hampshire
Brooke, John P. - San Jose State C.
Brooks, Harvey K. - U. of Florida
Brown, G. A. - U. of Rhode Island
Brown, M. Vertner - City U. of New York
Brown, Steven - Oregon Inst. of Marine Biology
Browzin, B. S. - Catholic U. of America
Brusca, Gary - Humboldt State C.
Bryant, William R. - Texas A&M U.
Bryson, Reid A. - U. of Wisconsin
Buck, John D. - U. of Connecticut
Bullock, W. L. - U. of New Hampshire
Burbank, N. - U. of Hawaii
Burke, W. T. - Long Island U.
Burkhart, M. D. - Graduate School, USDA
Burkholder, Paul - Columbia U.
Burns, Robert E. - U. of Washington
Burrell, David C. - U. of Alaska
Bursey, M. M. - U. of North Carolina
Burt, Wayne V. - Oregon State U.
Burton, Sheril D. - U. of Alaska
Button, Don K. - U. of Alaska
Byrne, John V. - Oregon State U.
Cahn, Phyllis - Long Island U.
Capp, Martin P. - San Diego State C.
Carey, Andrew G. - Oregon State U.
Carlson, Clarence A. - Cornell U.
Carozzi, Albert V. - U. of Illinois
Carpenter, James H. - Johns Hopkins U.
Carrier, Geoerge F. - Harvard U.
Carritt, Dayton E. - Mass. Inst. of Tech.
Carver, Robert E. - U. of Georgia
Cerame-Vivas, Miximo J. - U. of Puerto Rico
Chaet, Alfred B. - U. of West Florida
Chamberlain, T. K. - U. of Hawaii
Chambers, Leslie A. - U. of Southern California
Chapman, D. H. - U. of New Hampshire
Charlier, Roger H. - Illinois Teachers C. Chicago North
Charney, Jule G. - Mass. Inst. of Tech.
Chave, Keith E. - U. of Hawaii
Chermack, Eugene E. A. - New York U.
Chesbro, W. R. - U. of New Hampshire
Chestnut, Alphonse F. - U. of North Carolina
Cheung, T. S. - U. of Miami
Clark, Arnold M. - U. of Delaware
Clark, D. G. - U. of New Hampshire
Clark, David L. - U. of Wisconsin
Clark, Eugenie - City U. of New York
Clarke, George L. - Harvard U.
Claus, George - Long Island U.
Clayton, William H. - Texas A&M U.
Clench, William J. - Harvard

Clotworthy, John H. - U. of Miami
Clutter, Robert I. - U. of Hawaii
Coachman, Lawrence K. - U. of Washington
Coch, Nicholas K. - Long Island U.
Cochrane, John D. - Texas A&M U.
Cohen, Leonard - City U. of New York
Coher, E. I. - Long Island U.
Coke, J. L. - U. of North Carolina
Cole, Alan L. - U. of Michigan
Collier, F. N. - U. of North Carolina
Compton, Kenneth G. - U. of Miami
Conover, John T. - U. of Rhode Island
Cook, James R. - U. of Maine
Cooper, Milton W. - U. of Delaware
Copeland, B. J. - U. of Texas
Corcoran, Eugene F. - U. of Miami
Corell, R. W. - U. of New Hampshire
Corless, James T. - U. of Rhode Island
Cosenza, Benjamin J. - U. of Connecticut
Costlow, J. D. - Duke U.
Cottam, Grant - U. of Wisconsin
Cox, Charles S. - Scripps Inst. of Ocean.
Crandall, Stephen H. - Mass. Inst. of Tech.
Crandell, George F. - Humboldt State C.
Crawford, Ronald W. - San Diego State C.
Creager, Joe S. - U. of Washington
Croker, R. A. - U. of New Hampshire
Crook, L. T. - Catholic U. of America
Crouch, James E. - San Diego State C.
Curl, Herbert C., Jr. - Oregon State U.
Curray, Joseph R. - Scripps Inst. of Ocean.
Cutress, Charles E. - U. of Puerto Rico
Cuzon du Rest, Rene P. - Graduate School, USDA
Dahlberg, Michael D. - U. of Georgia
Daiber, Franklin C. - U. of Delaware
Darby, Richard L. - San Diego State C.
Davidson, Benjamin - New York U.
Davidson, James B. - Florida Atlantic U.
Davis, William J. - Virginia Inst. of Mar. Sci.
Dean, David - U. of Maine
Dearborn, John H. - U. of Maine
Degani, Meir H. - State U. of New York Maritime C.
Dehlinger, Peter - Oregon State U.
Deland, Raymond J. - New York U.
Denner, Warren W. - Naval Postgraduate School
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de Sylva, Donald P. - U. of Miami
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## DEGREES GRANTED, BY UNIVERSITY

| | Oceanography | Marine Sciences | Ocean Engineering | Fisheries | Other* |
|---|---|---|---|---|---|
| University of Alaska | M.S., Ph.D. | M.S., Ph.D. | | | M.S. |
| University of Bridgeport | | | M.S., Ph.D. | | M.S., Ph.D. |
| Catholic University of America | | | | | B.A., B.S.,<br>M.S., Ph.D. |
| University of California, Davis | | | | | |
| Cape Fear Technical Institute | | | | | Associate in Applied Science in Marine Technology |
| | | | | | M.S., Ph.D. |
| University of Chicago | B.S., M.A., Ph.D. | | | | |
| City College of the City University of New York | | M.A., Ph.D. | | | |
| Columbia University | | M.S., Ph.D. | | | Ph.D. |
| University of Connecticut | Ph.D. | B.S. | | | M.A., M.S. |
| Cornell University | | Ph.D. | | | |
| University of Delaware | M.A., Ph.D. | M.A., Ph.D. | | | M.S., Ph.D. |
| Duke University | | | | | |
| University of Florida | | | B.S. | | |
| Florida Atlantic University | | | | | |
| Florida Institute of Technology | B.S., M.S. | | | | B.S. |
| Florida Presbyterian College | | | | | |
| Florida State University | M.S., Ph.D. | | | | M.S., Ph.D. |
| University of Georgia | | | | | |
| Graduate School, USDA | Certificate of Accomplishment | | | | B.A., M.A., Ph.D. |
| Harvard University | | | | | |
| University of Hawaii | M.S., Ph.D. | | M.S. | B.S., M.S. | B.A., M.A. |
| Humboldt State College | B.S. | | | | |

|  | Oceanography | Marine Sciences | Ocean Engineering | Fisheries | Other* |
|---|---|---|---|---|---|
| Johns Hopkins University | M.A., Ph.D. |  |  |  |  |
| University of Illinois | M.S., Ph.D. |  |  |  |  |
| Illinois Teachers College Chicago-North |  |  |  |  | B.S., M.A. |
| Lehigh University |  | M.S., Ph.D. |  |  |  |
| Long Island University C.W. Post College |  | M.S. |  |  |  |
| Long Island University Southampton College |  | B.A. |  |  |  |
| University of Maine |  |  |  |  | M.S., Ph.D. |
| Massachusetts Institute of Technology | M.S., Ph.D. D.Sc. |  | M.S., Ph.D. D.Sc. |  |  |
| University of Miami |  | M.S., Ph.D. | M.S. |  |  |
| University of Michigan | B.S., M.S., Ph.D. |  |  |  |  |
| Naval Post Graduate School | M.S. |  |  |  |  |
| University of New Hampshire |  |  |  |  | M.A., M.S., Ph.D. |
| New York University | B.S., M.S., Ph.D. |  |  |  |  |
| University of North Carolina |  |  |  |  | B.S., M.S., Ph.D. |
| North Carolina State University |  |  |  |  | M.S., D.Sc. |
| Northeastern University |  |  |  |  | B.S. |
| Nova University | Ph.D. |  |  |  |  |
| State University of New York Maritime College | B.S. |  |  |  |  |
| Oregon Institute of Marine Biology |  |  |  |  | B.S., M.S., Ph.D. |
| Oregon State University | M.A., M.S., Ph.D. |  |  |  |  |
| University of the Pacific |  |  |  |  | M.S. |
| Pomona College |  |  |  |  |  |
| University of Puerto Rico |  |  |  |  | M.S. |

|  | Oceanography | Marine Sciences | Ocean Engineering | Fisheries | Other* |
|---|---|---|---|---|---|
| Rensselaer Polytechnic Institute |  |  |  |  | B.S., M.S., Ph.D. |
| University of Rhode Island | M.S., Ph.D. |  | M.S., Ph.D. |  |  |
| San Diego State College |  |  |  |  | B.A., B.S., M.A. M.S., Ph.D. |
| San Jose State College | B.S., M.S. |  |  |  |  |
| Scripps Institution of Oceanography | M.S., Ph.D. |  |  |  |  |
| Southern Maine Vocational Technical Institute |  |  |  |  | Diploma in various fields |
| Southeastern Massachusetts Technological Institute |  | B.S. |  |  | B.S. |
| University of Southern California | M.A., M.S. Ph.D. | M.S., Ph.D. |  |  |  |
| University of South Florida |  |  |  |  |  |
| Stanford University | Ph.D. |  |  |  |  |
| Suffolk County Community College |  |  |  |  | Associate in Applied Science |
| University of Texas |  | M.S., Ph.D. |  |  |  |
| Texas A&M University | M.S., Ph.D. |  |  |  |  |
| Virginia Institute of Marine Science |  | M.A., Ph.D. |  |  |  |
| Walla Walla College |  | B.A., B.S., M.A. |  |  |  |
| University of Washington | B.A., B.S., M.S., Ph.D. |  |  |  |  |
| University of Washington College of Fisheries |  |  |  | B.S., M.S., Ph.D. |  |
| University of West Florida |  |  |  |  | B.S. |
| University of Wisconsin | Ph.D. |  |  |  | Ph.D. |
| Yale University |  |  |  |  |  |

*Other - Denotes that courses are applied to classical degrees and closely related degrees.

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